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ART. I.—*Contributions to Meteorology; being results derived from an examination of the observations of the United States Signal Service, and from other sources;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Seventeenth paper. With three plates.

[Read before the National Academy of Sciences, Washington, April 18, 1882.]

Relation of rain areas to areas of low pressure.

IN my seventh paper, I examined all those cases in which the total rain-fall at all the stations of the United States Signal Service amounted to at least eight inches in eight hours, during a period of fifteen months. As the tri-daily observations have since that time been published for twenty-two additional months (viz: from Dec. 1873, to Jan. 1875, inclusive, and from Jan. 1877, to Aug. 1877) I propose to extend the examination to these later observations. The following table exhibits all the cases from Dec. 1873, to Jan. 1875, in which the total rain-fall at all the stations amounted to at least nine inches in eight hours; also all the cases from Jan., 1877, to June, 1877, in which the total rain-fall amounted to at least ten inches in eight hours; and for July and August, 1877, amounted to eleven inches in eight hours. This change in the amount of rain-fall adopted as the standard, was rendered necessary by the gradually increased number of the stations of observation.

In the following table column first shows the reference num-

Total rainfall at all the stations amounting to at least nine inches in eight hours.

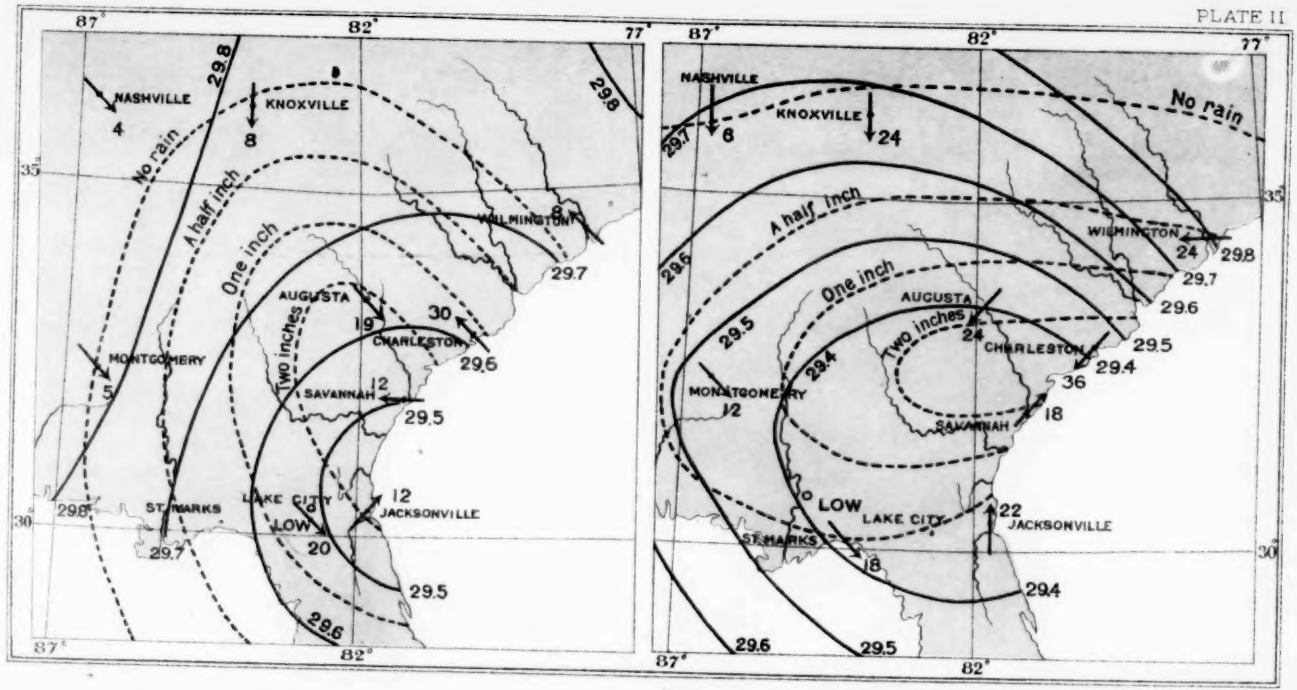
No.	Date.	Total rain.	Station of greatest rain.	Rain at do	Low moved.		Bar. change in 8 hours.		Tem. cha'e 24 hours.		Rain, areas.	Highest wind.
					Direct'n	Rate.	Front	Rear.	Fro't	Rear.		
	1873.											
1	Dec. 3–1	10·66	St. Louis	1·35	N.77 E.	22	−·13	+·06	+ 6	−20	4	24 S.W.NW.
2	3–2	10·87	Indianapolis	2·32	S.68W.	12	−·18	−·10	−12	− 3	1	36 SW.
3	3–3	15·06	Louisville	2·30	N.31E.	28	−·32	+·07	+ 1	−39	2	43 W.
4	12–1	10·51	Cleveland	1·12	N.63E.	51	−·08	+·05	+12	− 5	2	20N.NW.SW.
	1874.											
5	Jan. 6–2	12·65	Wilmington	1·35	S.78E.	22	−·18	−·10	+ 3	−13	3	31 NE.
6	7–1	11·81	Wilmington	1·03	N.20E.	38	−·13	+·10	+22	−21	3	26 E.
7	7–2	9·69	New York	1 68	N.22E.	12	−·12	+·04	+ 4	+ 4	3	20 SW.E.
8	22–1	10·25	St. Louis	1·52	S.43E.	13	−·15	+·18	+26	−14	3	24 S.
9	27–2	10·28	Rochester	1·16	S.80E.	32	−·15	+·24	0	− 7	5	38 NE.
10	Feb. 13–1	10·75	Cairo	1·91	S.48E.	28	−·07	+·38	+21	−11	3	28 SE.S.
11	13–3	9·45	Baltimore	1·17	N.65E.	26	−·08	+·26	+ 5	−17	3	30 S.
12	21–1	9 78	Cincinnati	1·25	N.58E.	37	−·02	+·16	+11	− 2	1	25 NW.
13	21–2	12·04	Cincinnati	1·45	N.62E.	41	−·03	+·08	+ 3	0	1	28 S.SW.
14	23–1	10·05	Erie	0·76	N.40E.	39	−·45	+·22	+ 6	− 7	5	65 E.
15	March 4–2	10·23	Eastport	2·08	S.45E.	21	−·30	+·12	+ 5	−13	1	65 SE.
16	6–1	10·98	Memphis	2·02	S.74E.	21	−·19	+·05	+ 3	− 3	2	24 SE.
17	7–1	9·40	Montgomery	1·19	N.49E.	26	−·40	+·23	+ 1	− 8	3	36 W.
18	16–2	9·43	Montgomery	1·32		0	−·09	−·09	− 6	− 6	2	36 SE.
19	April 7–1	9·38	Shreveport	2·18	S.34E.	19					1	24 E.
20	8–2	9·70	Vicksburg	3·67	S.77E.	16	−·07	+·04	0	−20	1	28 N.NE.
21	9–1	9·46	Knoxville	0·90	N.30E.	28	−·19	+·14	0	−14	4	25 S.
22	19–2	14·61	Vicksburg	2·49	N.16E.	25	−·42	·00	0	0	2	28 E.
23	19–3	9·31	Omaha	0·87	N.42E.	17	−·16	−·04	0	− 5	5	32 NE.
24	20–1	14·38	Milwaukee	1·43	N.50E.	38	−·15	+·22	+ 1	−10	6	34 E.
25	20–2	9·38	New London	0·91	N.74E.	52	−·24	+·43	0	− 1	2	32 S.
26	25–2	10·04	Knoxville	1·38	N.58E.	39	−·40	+·18	+ 3	− 2	3	38 E.
27	July 4–2	10·22	New Orleans	3·25	S.40E.	26	−·06	+·19	+ 6	0	2	24 N.S.
28	4–3	9·77	New Orleans	2·12	S.65E.	24	−·06	+·09	+ 2	− 2	5	40 NW.
29	Aug. 8–1	11·02	New London	4·45	N.65E.	36	−·10	+·01	+ 6	− 1	4	20 SW.
30	8–2	11·42	New London	3·90	South.	18	−·28	−·01	+ 5	− 5	4	18 W.NW.
31	8–3	9·23	New London	3·40	S.47E.	17	−·17	+·12	0	− 2	4	24 W.
32	21–3	10·16	Chicago	2·00	S.29W.	20	+·04	+·10	− 3	−10	4	18 SE.NE.
33	Sept. 16–1	9·39	Wilmington	2·04	S.78E.	14	−·06	+·01	− 1	+ 2	3	19 NE.
34	16–2	9·11	Washington	2·37	S.72W.	9	−·10	−·04	0	0	3	22 NE.
35	18–3	10·27	Dubuque	1·94	N.46E.	32	−·02	+·33	− 2	−15	2	20 E.NW.
36	19–1	9·53	Memphis	1·15	N.25E.	48	−·32	+·22	+ 6	−11	4	22 S.NW.
37	28–1	13·01	Savannah	2·80	N.71E.	20	−·36	−·03	− 1	−12	2	30 SE.
38	Nov. 22–3	13·25	Cincinnati	1·61	N.61E.	40	−·40	+·47	+12	− 2	2	42 SE.
39	23–1	21·45	Barnegat	1·65	N.45E.	36	−·66	+·33	+ 6	0	3	37 W.
40	23–2	16·93	Portland, Me.	1·62	N.63E.	18	−·12	+·45	+ 6	− 5	3	58 NE.
41	29–1	10·75	Washington	0·88	N.35E.	71	−·35	−·03	+11	+ 2	1	50 NE.
42	29–2	13·31	Eastport	1·97	N.64E.	29	−·60	+·01	+16	− 7	5	70 S.
43	Dec. 7–1	14·83	Cape Henry	1·50	N.35E.	23	−·10	·00	+10	0	2	24 NE.
44	20–2	14·00	Norfolk	1·26	N.81E.	52	−·53	+·35	+ 3	− 6	2	45 NE.
	1875.											
45	Jan. 2–1	14·04	Knoxville	1·03	S.51E.	28	−·44	·00	+14	− 9	4	28 N.NW.
46	7–3	10·13	Long Branch	0·80	N.46E.	41	−·17	−·02	+ 7	− 1	1	40 NE.
47	24–2	15·10	Barnegat	1·30	N.86E.	32	−·27	+·10	+ 7	− 5	4	35 W.
	1877.											
48	Jan. 1–2	10·95	Cape Hatteras	1·95	N.49E.	54	−·70	+·21	+ 2	− 6	3	50 E.
49	7–1	13·82	New London	1·60	N.29E.	45	−·78	+·10	+35	0	2	30 NE.SW.
50	7–2	11·22	Halifax	1·30	N.45E.	41	−·86	+·41	+16	+11	2	32 W.

RAIN-FALL FROM DEC. 1 TO DEC. 5. 1873 PLATE III.

PLATE II

RAIN AREA 1874 SEPT. 28th 7.35 A.M.

RAIN AREA 1877 APRIL 13th 7.35 A.M.



No.	Date.	Total rain.	Station of greatest rain.	Rain at do	Low moved		Bar. change in 8 hours.		Tem. cha'e 24 hours.		Rain. areas.	Highest wind.
					Direct'n	Rate.	Front	Rear.	Fro't	Rear.		
	1877.											
51	Jan. 15–2	13·28	Louisville	1·56	N.70E.	44	−·35	+·44	+ 8	−18	3	48 N.
52	March 2–1	14·11	St. Marks	1·81	N.31E.	32	−·49	+·10	+11	− 4	6	42 S.
53	2–2	18·96	Charleston	1·40	N.44E.	44	−·36	+·24	00	− 9	3	40 S.
54	8–2	15·51	Montgomery	1·58	N.72E.	26	−·41	+·09	00	−32	3	34 S.
55	8–3	12·13	Knoxville	0·90	N.57E.	39	−·24	+·12	+ 8	−12	5	47 S.
56	9–1	22·05	Cape Henry	1·46	N.51E.	35	−·48	+·29	+28	−22	6	50 S.
57	26–1	10·36	Cape Hatteras	1·39	N.60E.	19	−·13	+·07	+ 3	−10	3	32 N.NE.E.
58	26–2	18·44	New London	2·04	N.69E.	10	−·10	+·02	+ 1	− 8	2	38 N.
59	April 8–2	12·60	Charleston	3·70	S.13E.	4	− 02	+·03	0	− 1	4	36 NE.
60	13–1	12·24	Charleston	5·20	N.70E.	36	−·40	·00	+12	− 8	1	36 NE.
61	18–1	10·83	Memphis	1·60	S.18E.	21	−·12	+·03	− 2	− 5	2	32 NW.
62	19–1	15·76	Dubuque	1·55	N.82E.	21	−·05	+·21	− 2	− 6	5	30 N.
63	19–2	17·47	Milwaukee	1·37	N.84E.	26	−·08	+·15	− 6	−18	3	28 N.S.
64	28–2	11·46	St. Marks	1·34	N.85E.	36	−·23	+·13	+15	−16	3	36 N.
65	June 6–3	11·08	New London	2·13	S.76E.	12	+·05	+·10	0	− 4	5	16 NE.E.
66	8–2	12·92	Memphis	5·26	N.56E.	44	−·13	+·11	− 4	−18	4	38 N.
67	8–3	10·39	Corsicana	1·89	N.46E.	41	−·06	+·17	+ 3	−10	5	24 S.
68	21–3	14·24	Washington	2·17	N.47E.	39	−·12	+·04	− 7	− 5	2	22 S.
69	July 16–2	14·21	Uvalde, Tex.	6·00	S.80E.	32	−·07	−·03	+ 3	+ 2	3	30 SW.
70	19–2	14·51	Mt. Washin'n	2·04	N.64E.	17	−·04	+·09	− 4	− 4	6	32 S.
71	20–1	11·05	Philadelphia	1·75	N.10E.	25		+·08		0	4	18 NW.S.
72	28–2	11·79	Decatur, Tex.	2·00	N.82E.	21	−·07	+·05	0	0	3	20 SE.
73	Aug. 9–2	12·54	R. Grande C'y	2·65	S.86E.	16	−·08	·00	− 3	−15	7	28 SW.
74	31–2	11·76	Detroit	1·78	S.61E.	29	−·16	+·16	0	− 2	6	31 S.

ber; column second shows the day and hour of observation (the numeral one following a date denotes the 7.35 A. M. observation; two denotes 4.35 P. M.; and three denotes 11 P. M.); column third shows in inches the total rain-fall at all the stations since the preceding observation. Unfortunately these intervals are not equal, being severally 9^h; $6^h\ 25^m$; and $8^h\ 35^m$. Column fourth shows the station at which the greatest rain-fall was recorded. Column fifth shows (in inches) the amount of rain recorded at the station mentioned in column fourth; column sixth shows the direction in which the center of least pressure advanced during the preceding eight hours; column seventh shows the rate (in miles per hour) at which this low center advanced; column eighth shows (in decimals of an inch) the change of the barometer during the preceding eight hours at the place occupied by the low center at the date given in column second; column ninth shows the change of the barometer for the same time at the place occupied by the low center at the preceding observation; column tenth shows the change of temperature during the preceding twenty-four hours at the place occupied by the low center at the date given in column second; column eleventh shows the change of temperature for the same time at the place occupied by the low center at the preceding observation; column twelfth shows the num-

ber of rain areas at which the rain-fall since the preceding observation amounted to at least one-half inch; column thirteenth shows the velocity (in miles per hour), and also the direction, of the highest wind reported at any of the stations which could be regarded as included within the influence of the low barometer traced in columns sixth and seventh. Occasionally it happened that the same velocity was reported at several different stations. In such cases the direction of the wind is given for each of these stations.

For each of the cases named in this table, the curves of one-half inch rain-fall, and also of one inch rain-fall have been carefully drawn upon the Signal Service maps. These curves show the form and magnitude of the rain-areas and their position with reference to the center of low pressure. The central portion of two of these maps is exhibited on Plate II. The character of these results cannot be fully exhibited without the publication of the entire series of maps; but since such a course is impracticable, I have adopted the following artifice. I took a sheet of transparent paper, and ruled upon it two lines at right angles to each other; one line representing a meridian and the other a parallel of latitude; the point of intersection of these lines being designed to represent a center of low pressure. Beginning with the first date in the table, I marked upon the Signal Service map the center of low pressure for that date, and also the center of low pressure for the last preceding date of observation. The point mid-way between these two centers was regarded as the position of the low center for the middle of the period to which the reported rain-fall corresponded. Placing the center of the sheet of transparent paper over this point of the Signal Service map, I marked upon the paper the position of each of the rain centers for the given date. The rain area in which the fall was greatest was indicated by a small circle; the other rain-areas for the same date were indicated by a cross. In like manner, the position of the rain-areas for each of the dates in the table, was indicated. The results are given upon a reduced scale on Plate I. For convenience of comparison, four large circles are drawn with radii of 250, 500, 750 and 1000 miles from the low center, and a few of the rain centers have numbers attached to them corresponding to the numbers in the table on page 2. Rain-areas distant more than 1000 miles from the low center are not represented on this plate.

One of the most noticeable facts connected with these great rain storms is the large number of rain-centers prevailing simultaneously, and often quite distinct from each other. Plate II, accompanying my seventh paper, shows eight such centers; and at five of them the rain exceeded a half inch.

The table on page 2 shows one case in which there were seven rain-areas exceeding a half inch in amount; it shows six cases in which there were as many as six such areas; fifteen cases in which there were as many as five such areas; twenty-seven cases of four such areas; forty-eight cases of three such areas; and only nine cases in which there was not more than one rain area in which the rain-fall exceeded a half inch. Indeed if the stations of observation were sufficiently numerous, it is quite possible they would show that in every one of these storms there was more than one rain-area amounting to a half inch. This multitude of rain-centers appears to be intimately connected with the complex character of most storms.

If we compare the principal rain-centers of these storms (represented on Plate I by small circles) we shall find that their average distance from the center of low pressure is very nearly 400 miles. In my seventh paper this distance was stated to be 300 miles; but this number represents the distance of the rain-center from the center of low pressure at the date of observation; whereas in the present paper, the distance is measured from the position of the low center at the middle of the period during which the given rain was falling; so that these two results accord pretty well with each other.

An inspection of Plate I shows that there is a marked predominance of rain-centers on the east side of the low center, and that they occur most frequently in the northeast quadrant. In the following table, column second shows, for each of the four quadrants, the total number of rain-areas in which the rain-fall amounted to at least a half inch; and column third shows the number of cases in which the principal rain-center was found in each of the quadrants.

Quadrants.	Rain centers. Half-inch.	Greatest.
Northeast	86	31
Southeast	71	27
Southwest	41	9
Northwest	18	1

Plate I shows only those rain-areas which were situated within a distance of 1000 miles from the principal low center. In several of the cases examined, the greatest rain-fall occurred in the extreme southern portion of the United States, when the low center was in the extreme northern portion. This is the reason why the sum of the numbers in column third is less than the number of cases included in the table on page 2.

Those cases in which the greatest rain-fall occurred in the western quadrants require special examination, and for convenience of reference they are designated on Plate I by the same numbers as in the table on page 2; also all the cases in

which the principal rain-center was more than 500 miles south of the center of least pressure are designated by appropriate numbers. The following table shows the nine cases in which the principal rain center was south of the low center more than 500 miles and less than 1000 miles. Column first shows the reference number taken from the table on page 2 ; column second shows the date of occurrence ; column third shows the station at which the rain-fall was greatest, and column fourth shows the latitude of the station.

No.	Date.	Station.	Latitude.
17	1874, March 7–1	Montgomery	32° 22′
36	Sept. 19–1	Memphis	35 7
45	1875, Jan. 2–1	Knoxville	35 56
52	1877, March 2–1	St. Mark's	30 10
53	March 2–2	Charleston	32 45
54	March 8–2	Montgomery	32 22
64	April 28–2	St. Mark's	30 10
67	June 8 3	Corsicana	32 5
71	July 20–1	Philadelphia	39 57

We see that all but one of these stations were south of lat. 36° and the rain in these cases appears to have resulted from opposing winds attending the advance of a wave of high pressure from the west or northwest. In each of the cases there were indications of a cyclonic movement of the winds which was of a local character and of small geographical extent, and produced only a slight effect upon the barometer. These rain-areas were not of very great extent, the majority of them being less than 200 miles in their longest diameter. No. 71 was of very small dimensions, as will appear from the following table which shows the rain-fall for eight hours at all the stations within 175 miles of Philadelphia. The stations are arranged in the order of longitude from west to east.

Washington	0·00 inch.	Atlantic City	0·36 inch.
Baltimore	0·00 "	Barnegat	0·05 "
Philadelphia	1·75 "	Sandy Hook	0·08 "
Cape May	0·44 "	New York	0·07 "

In the nine cases above enumerated, the rain-fall had apparently very little influence upon the direction in which the principal low center advanced, or upon its rate of progress. This result accords with the conclusions arrived at in my sixth paper.

There remain only six other cases in which the principal rain-center was in either of the western quadrants, viz: Nos. 8, 10, 23, 41, 55 and 68.

In No. 8 the lowest isobar (29·70) formed an oval whose

length was four and a half times its breadth, having its longest diameter directed towards the northeast, St. Louis being near the southwestern extremity of this oval, and the pressure at St. Louis was only 0·04 inch above the lowest pressure reported at any station.

In No. 10 the isobar 29·50 formed a long oval whose principal axis was directed towards the northeast, Cairo being near the southwestern extremity of this oval, and there were indications of a cyclonic movement of the winds of a local character about Cairo.

In No. 23 the greatest precipitation (0·87 inch) was at Omaha on the northwest side of the low center; but at Cincinnati on the east side the rain-fall was 0·80 inch and the rain-area about Cincinnati was decidedly more extensive than that about Omaha. Under these circumstances the low center advanced eastward, but at a very slow rate, and the precipitation at Omaha apparently served to retard the eastward movement of the low center.

In No. 41 the lowest isobar formed a long oval directed towards the N.N.E. and extending beyond the stations of observation; so that the amount of the precipitation on the northeast side of the low center is not fully known. There was however a considerable fall of snow during the preceding sixteen hours at several of the stations north of the low center. The following are the amounts at four of the stations for the two periods of eight hours each, the snow being expressed in its equivalent of water. Kingston 0·42+0·34=0·76 inch; Ottawa 0·45+0·30=0·75 inch; Montreal 0·20+0·30=0·50 inch; Quebec 0·10+0 27=0·37 inch. It is probable that a considerable fall of snow extended much further northward.

In No. 55 the isobar 29·20 formed an oval whose length was more than double its breadth with its axis directed towards the northeast, and on the northeast side was a rain area of much greater extent than that about Knoxville. The rain-fall at Knoxville was 0·90 inch, and that at Oswego on the northeast side was 0·63 inch.

In No. 68 the lowest isobar is incomplete, but is evidently much elongated towards the north, and extends into Canada beyond the stations of observation.

In order to render this comparison more complete, I will include the similar cases mentioned in my seventh paper. If we refer each rain-area to the position of the low center at the middle of the period during which the reported rain was falling, and omit those cases in which the principal rain-center was more than 500 miles south of the low center, the following are the only remaining cases in which the principal rain-center appeared to be west of the low center, viz: Nos. 14, 26, 46, 47 and 53.

In No. 14 it seems probable that the rain-fall reported at Keokuk did not all fall during the preceding eight hours, but represents the entire rain-fall for the preceding twenty-four hours. This is indicated by a comparison of the record at Keokuk with that at the neighboring stations St. Louis and Davenport. The following is a copy of the record.

	January 1.3		January 2.1		January 2.2		Rain. 24 h.
	Weather.	Rain.	Weather.	Rain.	Weather.	Rain.	
Keokuk	Light rain	----	Light rain	----	Light snow	1·63	1·63
St. Louis	Heavy rain	0·30	Foggy	0·64	Cloudy	0·32	1·26
Davenport	Cloudy	----	Light rain	1·01	Light rain	0·10	1·11

At St. Louis, up to Jan. 2.1, the rain in sixteen hours amounted to 0·94 inch; and at Davenport it amounted to 1·01 inch, while at Keokuk (an intermediate station) no rain is recorded in the rain column although rain was reported in the weather column both at Jan. 1.3 and Jan. 2.1. It seems evident that the observer at Keokuk neglected to measure the rain until Jan. 2.2, and that a portion of the amount recorded for Jan. 2.2 must have fallen before Jan. 2.1. If this conclusion is correct, then the observations indicate that the principal rain-center for Jan. 2.2 was on the east side of the low center.

In No. 26 the principal rain-center was 137 miles northwest of the low center, and during the succeeding eight hours the low center advanced 156 miles towards the northwest.

In Nos. 46 and 47 the principal rain-center was northwest of the low center, and the low center advanced towards the northwest, as was fully shown in my seventh paper.

In No. 53 the principal rain-center was 290 miles southwest of the low center. At Nov. 23.3 the lowest isobar formed a very elongated oval whose principal axis extended from Vicksburg to Lake Erie, and the heaviest rain occurred near Vicksburg, around which place prevailed a very decided cyclonic movement of the winds. There was at the same time in the neighborhood of Lake Erie a fall of rain and snow of less amount, but extending over a greater area.

From this comparison we find that during the entire period of the published tri-daily observations (thirty-seven months), if we exclude the cases in which the rain-center was more than 500 miles south of the low center, there were but six cases of great rain storms in which the principal rain-center was southwest of the low center, and in each of these cases the lowest isobar formed an oval whose longest diameter was from three to five times its shortest diameter, and the longest diameter was directed towards the northeast. The principal rain-center appeared to be in the southwest portion of this oval; but at

the same time there prevailed in the northeast portion an area of rain of less depth but of equal, or greater, geographical extent, apparently indicating that a small depth of rain in the northern portion of the United States exerts an influence upon the center of low pressure, stronger than that exerted by a greater depth of rain in the southern portion.

We also find four cases in which the principal rain-center was northwest of the low center. In three of these cases the low center advanced towards the northwest. In the other case, although there was a station on the west side where the rain-fall was 0·07 inch greater than at any station on the east side, the rain-area on the east side was much the greatest in geographical extent, and the area of low pressure moved slowly eastward.

We thus learn that for the whole period of thirty-seven months, during great rain storms, the principal rain-center was most frequently situated nearly in the direction of the average progress of the low centers. The average direction of the storm tracks in column six of the table on page 2, is 15° north of east; which corresponds pretty nearly with the direction in which the principal rain-centers were most frequently found. This coincidence indicates an intimate connection between the rain-fall and the direction of a storm's progress. If however we make the comparison for each case separately, we find anomalies which appear to indicate either that the stations of observation are too distant from each other to show satisfactorily the form and position of the rain-areas, or else the direction of a storm's progress is influenced by other circumstances than the amount of rain-fall.

From an examination of columns eight and nine of the table on page 2, we see that the movement of a center of low pressure is attended by a fall of the barometer in front of a storm and a rise of the barometer in its rear; the average fall in front for these seventy-four cases being 0·23 inch in eight hours, and the average rise in the rear being 0·12 inch. There are only two cases in which the barometer rose in front of the low center, and in these cases the rise in the rear was greater than the rise in front. There are ten cases in which the barometer continued to fall for eight hours after the low center had passed, but in these cases the barometer on the front side fell more than it did in the rear. No. 18 is not regarded as an exception to this statement, for in that case the low center was apparently stationary for eight hours.

We also see from columns ten and eleven, that there was generally a rise of temperature in front of each storm, and a fall of temperature in the rear, the average change of temperature in one day from these seventy-four cases being 5° in front and 7°

in the rear. In the few cases in which there was a fall of temperature in the front, there was generally a greater fall in the rear; and when there was a rise of temperature in the rear, there was generally a greater rise in the front.

In my former papers I have given reasons which appear to me to indicate that the progress of a low center does *not* consist in a drifting of the general atmosphere eastward, but is rather like a wave whose characteristic feature is a diminution of pressure in front of the storm, and an increase of pressure in the rear. The question therefore which is now presented for our examination is, what causes the barometer to fall on one side of a storm's center, and to rise on the opposite side? I think it has been conclusively shown that it is only indirectly that the rain-fall contributes to this effect. The fall of the barometer results from the motion communicated to the air, and is due partly to the centrifugal force arising from the circulation about a center, but mainly (in ordinary storms) to the influence of the earth's rotation in deflecting a moving body to the right. By the precipitation of the vapor of the air and the heat which is thereby liberated, the surrounding air is drawn inward towards the region of precipitation; but the movement which this cause *tends* to produce, is modified by causes previously in operation. These causes consist mainly in the existing distribution of pressure, temperature and humidity, not only within the limits of the storm, but throughout an extensive region surrounding it on all sides. Moreover air has inertia, and when once set in rapid motion, it retains the motion acquired until this is overcome by the resistances encountered. In the case of a great winter storm, a system of winds is set in rapid motion over an area fifteen hundred miles or more in diameter. When a new force begins to operate tending to impress a different movement upon this vast mass of air, the effect must be, *not* that which the last cause would produce if it operated alone, but that which results from a combination of the last force with the preceding forces. This principle will assist us in detecting the influence of rain-fall in modifying the direction of a storm's progress. We see from Plate I that the greatest precipitation of vapor generally took place about four hundred miles east of the low center; and this precipitation developed a force which tended to divert the winds eastward, while a cold wind from the north or northwest was pressing in on the western side, and increasing the pressure in the rear of the storm.

The test of the correctness of this general explanation must consist in its successful application to each of the seventy-four cases in the table on page 2. I have made this comparison and consider the results to be satisfactory with the exception per-

haps of a few cases, in most of which the storm extended beyond the stations of observation, and adequate information respecting it has not been obtained. As the limits of this article will not allow me to take up each case in detail, I shall confine my notice to those cases which were most remarkable either for a very great velocity of progress, or a very small velocity. There are fourteen cases in which the low center advanced at a rate exceeding forty miles per hour, viz: Nos. 4, 13, 25, 36, 41, 44, 46, 48, 49, 50, 51, 53, 66 and 67. In Nos. 4, 13, 66 and 67 there was a trough of low pressure extending more than one thousand miles across the United States from southwest to northeast. A considerable fall of rain on the front side of the principal center of low pressure carried the low center forward with unusual velocity, although the change of pressure in eight hours was small. In Nos. 66 and 67 there was an area of high pressure on the northeast side and another on the northwest side, which condition seems to favor the rapid progress of low centers as shown in my twelfth paper. In No. 25 the conditions were very similar to those represented on Plate IV accompanying my twelfth paper, viz: a fall of rain and snow of great geographical extent on the northern side of the low center, associated with an area of high pressure on the northeast side and another on the northwest side. In Nos. 36 and 41 the lowest isobar formed a very elongated oval, whose longest diameter extended from southwest to northeast. The principal rain-fall reported was on the south side of the principal low center, but since the lowest isobar extended northward beyond the stations of observation, it is not known what the rain fall was on the northern side. These two cases were therefore apparently similar to Nos. 4, 13, 66 and 67. Moreover in No. 36 there was an area of high barometer on the northeast side and another on the northwest side. In Nos. 44, 46 and 48 the low center, which was already near the Atlantic coast, moved rapidly eastward, being apparently influenced by the great rain-fall near the coast. Many cases have been found in which a storm moving eastward from the United States to the Atlantic Ocean, has suddenly acquired a great increase of intensity, attended by a great fall of rain or snow. Nos. 44, 46 and 48 were apparently of this class. In Nos. 49 and 50 the low center was near the Atlantic coast, and adhered closely to the coast line, being preceded by a heavy fall of snow. Also in No. 46 there was an area of high barometer on the northeast side and another on the northwest side. In No. 51 there was also an area of high pressure on the northeast side and another on the northwest side, with heavy rain on the east side of the low center. Also the winds which attended the area of high pressure on the northwest were unusually violent, being forty-

eight miles an hour at Dodge city; thirty-six at Yankton, thirty-two at Leavenworth, and thirty-one at Escanaba. In No. 53 the low center had already reached Canada, so that the amount of rain fall on the front side of the low center is unknown.

Thus in each of these fourteen cases, whenever the observations furnish the requisite information, we find that a heavy fall of rain preceded the low center, and in six of the cases we find a special cause why a small change of pressure carried the low center forward with unusual velocity. Also in six cases we find an area of high pressure on the northeast side together with an area of high pressure on the northwest side, distant from the former about seventeen hundred miles. These facts are regarded as explaining and confirming the remark made on page 10, that the movement of centers of low pressure is modified by the distribution of pressure existing beyond the limits of the low area.

Among the seventy-four cases in the table on page 2, there are eleven in which the low center advanced at a rate not exceeding sixteen miles per hour, viz: Nos. 2, 7, 8, 18, 20, 33, 34, 58, 59, 65 and 73. In Nos. 2 and 8 there was a trough of low pressure extending more than one thousand miles across the United States from southwest to northeast. A considerable fall of rain on the southwest side of the principal center of low pressure, accompanied by a cyclonic movement of the winds, was apparently the cause of a small fall of the barometer on that side, which in No. 2 carried the center of low pressure towards the southwest, and in No. 8 towards the southeast. In Nos. 7, 33, 34, 58, 59, 65 and 73 an area of low pressure prevailed in the region between the Mississippi River and the Rocky Mountains, and in some of the cases extended as far as the Pacific Ocean. The influence of this low pressure extended eastward, and diverted the westerly winds which otherwise might have been expected to follow the first low center. This was apparently the reason why these low centers advanced so slowly, and in one case the low was diverted westward. In No. 18 the low center was near Fort Sully, but on account of the small number of stations of observation, the exact position of the center cannot be assigned. The observations however, show that for four days, from March 13th to 17th, an area of high pressure prevailed over the United States east of the Mississippi river, while a low pressure prevailed between the meridian of 100° and the Rocky Mountains, and this low area maintained nearly the same position during these four days. On the afternoon of March 17th, a high appeared on the coast of Oregon, which crossed the Rocky Mountains on the 19th, and as it advanced eastward, the low was apparently pushed forward

at about the same rate. This is one of numerous cases which appear to indicate that an area of low pressure cannot advance rapidly unless an area of high pressure advances behind it. The Signal Service observations also show numerous cases in which a low area has remained for several days nearly stationary between the Rocky Mountains and the meridian of 100°. In No. 20 there were unusually heavy rains on the north side of the low center and a violent cyclonic movement of the winds about this center, but on the west side of the low center the low pressure extended to a great distance, and a high pressure did not appear on the west side until April 9th, after which date the low moved eastward more rapidly.

Thus we see that nearly all of these cases of extremely slow motion apparently resulted from an unusual extension of a second area of low pressure on the western side. These cases of very slow motion, as well as those of very rapid motion, indicate that the direction of movement and rate of progress of a storm center do not depend exclusively upon the amount of rain-fall or upon the distribution of rain-fall within an area of low pressure, but also upon the distribution of pressure, temperature and humidity throughout an extensive region surrounding the low area on all sides. Moreover the influence of barometric pressure is generally much more obvious than that of temperature or humidity. An examination of the International Weather maps indicates how the progress of a storm center may be influenced by another storm prevailing at a distance of several thousand miles. We find from these maps that the entire northern hemisphere, north of lat. 30°, is generally covered by successive areas of high and low pressure which are advancing eastward with unequal velocities, and are daily undergoing important modifications. If one storm increases or diminishes in intensity, this change must affect the adjoining areas of high pressure, and this in turn must affect the areas of low pressure which prevail beyond these areas of high pressure. If one storm slackens in its rate of progress, it may be overtaken by another area of low pressure which is advancing from the west. If one storm advances with unusual rapidity, it may overtake another storm prevailing on its eastern side and may coalesce with it. While then the precipitation of the vapor of the air appears to be the chief source of that maintaining power which is necessary to sustain the action of violent storms, we cannot certainly predict the direction of movement and the rate of progress of an area of low pressure from a simple knowledge of the amount of rain-fall and position of the rain-areas within the limits of that low area.

The high winds which are uniformly found to prevail somewhere in the vicinity of a great fall of rain deserve particular

notice. In my seventh paper the average velocity of the wind at the stations of greatest rain-fall was found to be only ten miles per hour, but in each case there was, within the low area, some station where the wind attained a much greater velocity. From column eleventh of the table on page 2 it is seen that among the seventy-four cases recorded, there was no instance in which the wind did not attain a velocity of sixteen miles per hour at some one of the stations within the low area. We also see that in fifty-three of the cases the velocity rose as high as twenty-five miles per hour; in sixteen of the cases it rose to forty miles per hour; and in three cases it exceeded sixty miles per hour. These high velocities come from all points of the compass, but most frequently from the south and northeast. The southerly winds are slightly stronger than the northerly winds, and the easterly winds are decidedly stronger than the westerly winds. The most remarkable feature of the winds attending a great fall of rain is their very unequal force at stations not very remote from each other. This will appear from the following table which shows the direction and velocity of the wind at nine stations near the Gulf of St. Lawrence for Nos. 14, 15, 40, 41 and 42 of the table on page 2.

	No. 14.	No. 15.	No. 40.	No. 41.	No. 42.
Montreal	N. 19	N. 12	E. 11	N.W. 10	W. 5
Quebec	E. 65	N.E. 9	N.E. 58	N.E. 50	S.W. 19
Portland	N.E. 6	S. 12	N.E. 28	S.W. 20	Calm.
Eastport	E. 28	S. 20	S.E. 24	S. 22	N. 20
Father Point	N.E. 3	W. 4	N.E. 8	E. 11	W. 12
Chatham	Calm.	S. 11	Calm.	S. 10	S. 14
Cape Rosier	W. 1	S.E. 65	S.E. 5	S. 18	S. 70
Halifax	E. 10	S.E. 20	S.E. 17	S.E. 11	S. 33
Sydney	E. 1	S. 17	E. 2	S.E. 5	S. 16

In Nos. 14, 40 and 41 compare the velocity of the wind at Quebec with the velocities at Montreal and Father Point; also in Nos. 15 and 42 compare the velocity at Cape Rosier with the velocities at Chatham and Sydney. It seems difficult to explain these observations except by admitting that near the station where the wind attained its greatest velocity, there was a strong upward movement of the air, and that the void thus left in the lower stratum of the atmosphere was supplied by air flowing in with a smaller velocity from a much greater geographical area.

A similar conclusion is deduced from the observations made near the Atlantic coast for Nos. 44, 48, 53, 55 and 56 as shown in the following table.

	No. 44.	No. 48.	No. 53.	No. 55.	No. 56.
Wilmington	W. 32	W. 4	S.W. 14	S. 20	S.W. 19
Cape Hatteras	S.W. 27	S.E. 31	W. 8	S.E. 44	S. 50
Kitty Hawk		N.E. 30	S. 12	S. 47	S.W. 36
Norfolk	N.W. 16	E. 17	S.W. 13	S.W. 24	S.W. 27
Cape Henry	S.E. 9	E. 50	S. 12	S. 24	S. 20
Cape May	N.E. 28	N.E. 20	S. 34	S. 38	S. 45
Baltimore	N.E. 15	N.E. 8	S.E. 2	S. 16	S. 8
Barnegat	N.E. 25	E. 12	S. 40	S. 26	S. 46
Philadelphia	N.E. 20	E. 14	S.W. 19	S.W. 30	S.W. 40
Long Branch	N.E. 45				
Sandy Hook	N.E. 26		S.E. 32	S. 28	S. 48

In No. 44 compare the velocity of the wind at Long Branch with the velocities at Barnegat and Sandy Hook; in No. 48 compare Cape Henry with Norfolk and Cape May; in No. 53 compare Barnegat with Baltimore and Philadelphia; in Nos. 55 and 56 compare Cape Hatteras and Kitty Hawk with Wilmington and Norfolk.

We frequently find the winds blowing exactly toward each other, from two stations less than 100 miles apart. Generally such winds are feeble, but occasionally they are very strong, and in such cases we generally find that rain is falling in that vicinity. The following table shows the direction and velocity of the wind at Savannah, Charleston and Augusta in eight cases in which at two of these stations the winds were approaching each other at a rate of more than twenty miles per hour. The table also shows the rain-fall for the eight hours preceding and the eight hours following the date given in column second. Charleston is distant from Savannah eighty-five miles and from Augusta 125 miles; the distance from Savannah to Augusta is 104 miles.

No.	Date.	Savannah.			Charleston.			Augusta		
		Wind.	Rain.		Wind.	Rain.		Wind.	Rain.	
			Bef'e.	After.		Bef'e.	After.		Bef'e.	After.
1	'73. Feb. 6.3	S.W. 16	0·22	0·12	S. 18	0·02	0·30	N. 4	0·52	0·27
2	'74. May 4.1	E. 12	0·07	0 45	S.E. 4	1·37	0·52	N.W. 20	0·87	0 93
3	'74. June 27.2	S.E. 24	0·37	0·45	S. 9			N.W. 7		
4	'74. Sept. 28.1	E. 12	2·80	0·95	S.E. 30	1·29	2·57	N.W. 19	2·10	0·50
5	'74. Dec. 6.3	S.W. 12	0·05	0·10	S. 13	0·05	0·27	N. 8	1·02	
6	'77. April 3.2	S.E. 16			N.E. 11			N.W. 8		
7	'77. April 7.3	S.W. 8		0·60	N.E. 19			S.E. 12		1·52
8	'77. April 13.1	S.W. 18	1·98	0·30	N.E. 36	5·20	2 80	N.E. 24	1·76	0·90

Nos. 4 and 8 are represented on Plate II. The isobars for the dates given in the table are represented by continuous black lines; the rain-fall for the eight hours preceding the given dates is indicated by dotted lines. The outer dotted line shows the boundary of the rain region; the other dotted

lines show the boundaries of a half inch rain-fall—one inch rain-fall—and two inches rain-fall. The position of the center of low pressure four hours previous to the given dates, is shown by a small circle near the word LOW. The velocity of the wind at each station is indicated by the number placed near the point of the arrow at that station.

In No. 4 the winds at Charleston and Augusta were blowing towards each other with velocities of thirty and nineteen miles per hour, and the rain at Charleston amounted to 3·86 inches in sixteen hours. This case is the same as No. 37 on page 2.

In No. 8 the winds at Savannah and Charleston were blowing towards each other with velocities of eighteen and thirty-six miles per hour, and the fall of rain at Charleston amounted to eight inches in sixteen hours. This case is the same as No. 60 on page 3. The conclusion seems unavoidable that in these cases the air ascended from the earth's surface with great violence and was carried up to such a height that its vapor was condensed with unusual rapidity. It will also be observed that the greatest rain-fall occurred on the northeast side of the low center.

In order to determine the duration of great rain-falls, I proceeded in the manner described in my seventh paper. I selected all those cases in which any of the rain-falls mentioned in the table on page 2, for the years 1873, 4 and 5 were followed by at least four and a half inches of rain (total amount at all the stations) during a succeeding period of eight hours; and for the year 1877 were followed by at least five inches of rain during the next eight hours. The table on page 17 shows the result of this comparison. Columns seven, ten, thirteen, etc., generally show the station of greatest rain-fall for the given date; but whenever the station of greatest rain-fall was not apparently connected by a continuous rain-area with the station mentioned at the preceding observation, if there was a third station where the rain-fall was at least a half inch, and which could be thus connected with the first station, this third station has been inserted in the table instead of the second. This remark applies to the following cases, viz: No. 3 Albany, No. 8 St. Paul, No. 12 Cincinnati, No. 15 Boston, No. 17 Wilmington, New York and Philadelphia, No. 18 Duluth, No. 21 Cape Henry, No. 27 Boston, No. 28 Mt. Washington, No. 30 Memphis, No. 32 New London, No. 33 Charleston, No. 34 Cape May and No. 35 Atlantic City. By this mode of comparison, the continuous rain areas, in the cases named, are made to appear of longer duration than if the comparison had been restricted in all cases to the stations of greatest rain-fall. When a rain area is called continuous between two stations, it is to be understood that there was a belt of rain, amounting to at least a half inch in eight hours, connecting the two stations.

Heavy rain-fall continuing more than eight hours.

Heavy rain-fall continuing more than eight hours.

No.	Date.	Total rain.	Station of greatest rain.	Date.	Total rain.	Station of greatest rain.	Date.	Total rain.	Station of greatest rain.	Date.	Total rain.	Station of greatest rain.	Date.	Total rain.	Station of greatest rain.	Date.	Total rain.	Station of greatest rain.
1	'73. Dec. 3.1	10·66	St. Louis[1]	3.2	10·87	Indianapolis[2]	3.3	15·06	Louisville[3]	4.1	8·47	Knoxville[4]						
2	12.1	10·51	Cleveland[1]	12.2	7·01	Cincinnati[2]	12.3	6·69	Louisville[3]	13.1	6·55	Mobile	13.2	6·77	Boston			
3	'74. Jan. 6.2	12·65	Wilmington[1]	6.3	8·37	Lynchburg[2]	7.1	11·81	Wilmington[3]	7.2	9·69	New York[4]	7.3	6·82	Philadelphia[5]	8.1	5·67	Albany[6]
4	22.1	10·25	St. Louis[1]	22.2	8·30	Cairo[2]	22.3	5·84	Quebec									
5	27.2	10·28	Rochester	27.3	6·02	Montgomery	28.1	5·99	Ottawa	28.2	5·23	Rochester						
6	Feb. 13.1	10·75	Cairo[1]	13.2	7·70	Louisville[2]	13.3	9·45	Baltimore	14.1	7·32	Savannah[1]	14.2	4·88	Savannah[2]	14.3	6·45	Jacksonville[3]
7	21.1	9·78	Cincinnati[1]	21.2	12·04	Cincinnati[2]												
8	Mar. 6.1	10·98	Memphis[1]	6.2	5·21	Vicksburg[2]	6.3	5·82	Lacrosse[1]	7.1	9·40	St. Paul[2]						
9	16.2	9·43	Montgomery[1]	16.3	7·69	Mobile[2]	17.1	8·85	Wilmington[3]									
10	Apr. 7.1	9·38	Shreveport[1]	7.2	5·55	Vicksburg[2]												
11	8.2	9·70	Vicksburg[1]	8.3	6·45	Montgomery[2]	9.1	9·46	Knoxville[3]	9.2	8·41	Cairo	9.3	5·71	Baltimore[1]	10.1	8·42	New London[2]
12	19.2	14·61	Vicksburg[1]	19.3	9·31	Cincinnati[2]	20.1	14·38	Milwaukee	20.2	9·38	New London						
13	25.2	10·04	Knoxville	25.3	6·62	New London[1]	26.1	6·60	Boston[2]									
14	July 4.2	10·22	New Orleans[1]	4.3	9·77	New Orleans[2]												
15	Aug. 8.1	11·02	New London[1]	8.2	11·42	New London[2]	8.3	9·23	New London[3]	9.1	7.29	Boston[4]	9.2	4·61	New London[5]			
16	21.3	10·16	Chicago	22.1	5·61	Memphis[1]	22.2	6·36	Memphis[2]				[18.1	5·99	New York[4]	18.2	7·96	New York[5]
17	Sept. 16.1	9·39	Wilmington[1]	16.2	9·11	Wilmington[2]	16.3	7·60	Augusta	17.1	4·64	Cape May[1]	17.2	6·72	Philadelphia[2]	17.3	4·50	New York[3]
18	18.3	10·27	Dubuque[1]	19.1	9·53	Duluth[2]	19.2	7·51	Duluth[3]									
19	28.1	13·01	Savannah[1]	28.2	7·42	Charleston[2]												
20	Nov. 22.3	13·25	Cincinnati	23.1	21·45	Barnegat[1]	23.2	16·93	Portland[2]	23.3	5·97	Eastport[3]	24.1	5·61	Sydney[4]			
21	29.1	10·75	Washington[1]	29.2	13·31	Cape Henry[2]												
22	'75. Jan. 2.1	14·04	Knoxville	2.2	7·59	New London												
23	'77. Jan. 1.2	10·95	C. Hatteras[1]	1.3	5·04	Lynchburg[2]												
24	7.1	13·82	New London[1]	7.2	11·22	Halifax[2]												
25	15.2	13·28	Louisville	15.3	8·23	Milwaukee	16.1	9·81	Mt. Washin'n									
26	Mar. 2.1	14·11	St. Marks[1]	2.2	18·96	Charleston[2]	2.3	7·18	Portland, Me									
27	8.2	15·51	Montgomery[1]	8.3	12·13	Knoxville[2]	9.1	22·05	Cape Henry[1]	9.2	7·48	Boston[2]				[28.1	5·49	Mt. Washin'n[7]
28	26.1	10·36	C. Hatteras[1]	26.2	18·44	New London[2]	26.3	9·30	New London[3]	27.1	8·40	Mt. Washin'n[4]	27.2	6·69	Mt. Washin'n[5]	27.3	6·74	Mt. Washin'n[6]
29	Apr. 13.1	12·24	Charleston[1]	13.2	9·10	Charleston[2]	13.3	6·99	Norfolk[3]				[20.1	8·55	Lynchburg[2]	20.2	6·83	Sandy Hook
30	18.1	10·83	Memphis[1]	18.2	8·68	Memphis[2]	18.3	6·87	Cairo[3]	19.1	15·76	Dubuque[1]	19.2	17·47	Milwaukee[2]	19.3	9·25	Washington[1]
31	28.2	11·46	St. Marks	28.3	7·04	Pittsburgh												
32	June 6.3	11·08	New London[1]	7.1	8·24	New London[2]	[10.2	5·43	Savannah[1]	10.3	5·76	Charleston[2]	11.1	6·80	Wilmington[3]	11.2	8·62	Wilmington[4]
33	8.2	12·92	Memphis	8.3	10·39	Corsicana	9.1	9·99	Memphis	9.2	8·97	Port Huron[1]	9.3	6·43	Parry Sound[2]	10.1	6·64	Mobile
34	21.3	14·24	Washington[1]	22.1	6·12	Cape May[2]	22.2	5·31	Vicksburg									
35	July 19.2	14·51	Mt. Washin'n	19.3	5·61	Tucson, Ar.	20.1	11·05	Philadelphia[1]	20.2	9·69	Atlantic City[2]						
36	Aug. 31.2	11·76	Detroit[1]	31.3	6·15	Sandusky[2]												

We see from this table that in a period of twenty-one months, there were thirty-six cases in which a total rain-fall of nine inches in eight hours was followed by a total rain-fall of more than five inches during the next eight hours; there were twenty-five cases in which it was followed by a similar rain-fall during a third period of eight hours; there were sixteen cases in which it was followed by at least four and a half inches of rain during a fourth period of eight hours; there were ten cases of a fifth period; seven cases of a sixth period; four cases of a seventh period; three cases of an eighth period; and one case of a tenth period. These rain areas which succeeded each other in order of time, were not however in all cases continuous rain areas, nor were they even adjacent to each other. Those cases which were apparently thus related as forming continuous rain-areas, are indicated by the numerals 1, 2, 3, etc., attached to the names of the stations. We find that out of these thirty-six cases there were only fourteen cases in which the same rain-area continued for as much as three periods of eight hours; and in only seven cases did the same rain-area continue for more than three periods; that is, more than twenty-four hours.

We thus see that in the United States, rain areas, with a fall of at least a half inch in eight hours, seldom continue for more than twenty-four hours. This result accords very closely with that deduced in my seventh paper from observations of sixteen months. During the entire period of the published observations (thirty seven months) we find only nine cases in which the same rain-area, with a fall of at least a half inch in eight hours, continued longer than one day, making on an average three cases in a year, derived from a comparison of all the cases in which there was a total rain-fall of at least nine inches in eight hours at ninety stations. This result has an important bearing upon the philosophy of storms. It was objected to Espy's theory of storms that if his computations were correct, when rain had once commenced it would have the power of perpetuating itself; that is, it should be a veritable perpetual motion, and should never cease. The comparison of three years' observations however shows us that although considerable rain attends all great storms, or areas of low barometer, and these areas of low barometer can sometimes be traced through a distance of many thousand miles, yet the rain-fall in such a storm does not form a regular rain-belt of many thousand miles in length and of nearly uniform breadth, but rather a succession of rain areas grouped irregularly together. The continuity of the belt may not be absolutely broken, but its breadth and density exhibit great irregularities. While a storm is pursuing its path from the Rocky Mountains to the

Atlantic Ocean, the breadth of the rain-belt may vary from 100 or 200 miles to 1500 miles; and the amount of rain near the central line of the belt may vary from 4 or 5 inches to less than one-tenth of an inch.

In order to investigate this subject more fully, I have determined for each of the cases in the table on page 17, the total rain-fall at each of the stations during the period when it was included within the low area under investigation. The following table shows the total amount of rain-fall at each of the stations for No. 1 during the five days from Dec. 1 to Dec. 5, 1873, counting only the rain which fell within the low area; that is, while the barometer was below 30 inches. At Mobile, Montgomery and several other southern stations some rain fell during this period when the barometer was above 30 inches, but this rain is not included in the following table.

Rain-fall from Dec. 1st to Dec. 5th, 1873.

Station.	Rain.	Station.	Rain.	Station.	Rain.	Station.	Rain
Alpena,	0·26	Duluth,	0·15	Leavenworth,	0·77	P. Dover,	0·81
Augusta,	·00	Eastport,	·15	Louisville,	2·30	P. Stanley,	·92
Baltimore,	·01	Erie,	·41	Lynchburg,	·06	Portland,	·00
Boston,	·10	Escanaba,	1·12	Marquette,	·55	Punta Rassa,	·00
Breckenridge,	·11	Farther Point,	·12	Memphis,	·69	Quebec,	1·34
Buffalo,	·64	Ft. Benton,	·00	Milwaukee,	1·09	Rochester,	·26
Burlington,	·00	Ft. Garry,	·29	Mobile,	·00	Santa Fe,	·01
Cairo,	1·25	Ft. Gibson,	·57	Montgomery,	·00	Saugeen,	·55
Cape May,	·00	Ft. Sully,	·00	Montreal,	·37	Savannah,	·00
C. Rozier,	·05	Galveston,	·02	Mt. Washington,	·09	Shreveport,	1·41
Charleston,	·00	Grand Haven,	·44	Nashville,	1·90	St. Louis,	2·68
Chatham,	·01	Halifax,	·17	New London,	·08	St. Paul,	·13
Cheyenne,	·05	Indianapolis,	3·46	New Orleans,	·00	Sydney,	·00
Chicago,	1·20	Indianola,	·00	New York,	·01	Toledo,	2·07
Cincinnati,	2·47	Jacksonville,	·00	Norfolk,	·00	Toronto,	·26
Cleveland,	·64	Keokuk,	·98	Omaha,	·08	Vicksburg,	·03
Davenport,	1·21	Kingston,	·95	Oswego,	·49	Virginia C.,	·00
Denver,	·37	Knoxville,	1·66	Pembina,	·13	Washington,	·01
Detroit,	1·73	LaCrosse,	·86	Philadelphia,	·11	Wilmington,	·00
Dubuque,	·70	Lake City,	·00	Pittsburgh,	·42	Yankton,	·12

The numbers in this table are represented by curves on Plate III, which shows the boundary of the area having a total rain fall of one-tenth of an inch; also the area of a half inch rain-fall—one inch—two inches and three inches. We see that west of the meridian of 98° from Greenwich, the aggregate rain-fall for these five days was less than one-tenth of an inch; and as the low center advanced eastward, the rain-fall rapidly increased up to 3·46 inches at Indianapolis; after which it declined with almost equal rapidity, and in longitude 67° became reduced to one-tenth of an inch. The dotted line shows the course of the center of low pressure, its position at

the date of each observation being shown by the figures 2·1; 2·2; 2·3; 3·1, etc. During the progress of this storm, the pressure at the center of the low area underwent great changes. The following table shows for each of the dates, the lowest pressure reported at any of the stations.

Date.	Station.	Barom.	Date.	Station.	Barom.	Date.	Station.	Barom.
Dec. 2.1	Denver,	29·65	Dec. 3.2	Chicago,	29·37	Dec. 4.3	Chatham,	29·29
2.2	Leavenworth,	·55	3.3	Escanaba,	·08	5.1	C. Rozier,	29·65
2.3	Dubuque,	·52	4.1	Marquette,	28·91			
3.1	Escanaba,	·54	4.2	Quebec,	29·43			

We see that the pressure at the center of the low area decreased until Dec. 4, at 7½ A. M., and this was more than eight hours after the time when the rain-fall had reached its maximum; also the pressure slowly increased as the amount of rain-fall decreased. These facts appear to illustrate the inertia of the atmosphere; the minimum of pressure having occurred considerably later than the maximum of rain-fall, and the pressure was slowly restored even when the rain-fall had apparently well-nigh ceased.

The results obtained in this case accord substantially with those found in a large number of other cases. In all of the cases shown in the table on page 17, the rain-fall west of the meridian of 100° was well-nigh inappreciable, and the rain-fall increased rapidly as the low area moved eastward. Whenever there was a heavy rain-fall west of the meridian of 85°, the rain almost invariably declined before reaching the Atlantic coast. The heavy rain-falls near the Atlantic coast generally commence in the south and follow the Atlantic coast towards the northeast.

The facts here developed confirm the remark made in my 7th paper that "the forces which impart that movement to the air which is requisite to an abundant precipitation of its vapor, instead of deriving increased force from a great fall of rain, rapidly expand themselves and become exhausted." In the case of No. 1, the decrease in the rain-fall was apparently caused by a very cold westerly wind which followed the low area and attained in many places a velocity of 40 miles per hour, and in one place a velocity of 49 miles per hour. The following table shows the fall of temperature in 24 hours at various stations during the progress of this storm, and it will be noticed that these changes were independent of the ordinary diurnal variation of temperature.

Fall of temperature in 24 *hours, Dec.* 2–5, 1873.

Dec. 2.3	Cheyenne,	32°	Dec. 4.1	Chicago,	40°	Dec. 4.2	Memphis,	36°
	Denver,	37		Dubuque,	31		Nashville,	32
	Leavenworth,	36		Indianapolis,	50	Dec. 4.3	Detroit,	32
	Virginia City,	31		La Crosse,	34		Erie,	35
Dec. 3.1	Leavenworth,	37		Louisville,	31		Indianapolis,	30
Dec. 3.2	Keokuk,	36		Memphis,	31		Pittsburgh,	35
	Leavenworth,	35		Milwaukee,	43	Dec. 5.1	Oswego,	31
Dec. 3.3	Dubuque,	42		Nashville,	30		Rochester,	37
	St. Louis,	36		St. Louis,	41	Dec. 5.2	Norfolk,	30
Dec. 4.1	Cairo,	39	Dec. 4.2	Louisville,	33		Washington,	32

On page 14 it was remarked that in great rain-storms the easterly winds are generally much stronger than the westerly winds. In the case of No. 1 the westerly winds were much the strongest, as is shown by the following table which gives all the cases from Dec. 1.2 to Dec. 5.3 in which the velocity of the wind rose as high as 25 miles per hour at any of the stations except Mt. Washington and Pike's Peak. The table shows the direction of these high winds, and also their velocity in miles per hour.

High winds Dec. 1–5, 1873.

Dec.				Dec.				Dec.		
1.2	Grand Haven,	S.E.	29	3.3	Indianola,	N.E.	48	4.2	Buffalo,	S.W. 36
1.3	Escanaba,	S.E.	28		Keokuk,	W.	28		Eastport,	S.W. 32
2.2	Santa Fe,	S.W.	26		Kingston,	S.	27		Father Point,	S.W. 30
2.3	Cape Rosier,	S.W.	25		Knoxville,	S.	28		Gr'nd Haven	W. 39
	Davenport,	S.	28		Milwaukee,	S.W.	28		Milwaukee,	N. 29
	Grand Haven,	S.W.	30		St. Louis,	W.	43		Port Dover,	S.W. 27
3.2	Burlington,	S.	30	4.1	Alpena.	S.W.	40		Rochester,	W. 32
	Cape Rosier,	S.W.	42		Buffalo,	W.	32		Saugeen,	S.W. 30
	Indianola,	S.W.	36		Burlington,	S.	32		Toledo,	S. 28
	Knoxville,	S.	26		Chicago,	S.W.	38	4.3	Buffalo.	W. 40
	Vicksburg,	S.	25		Grand Haven,	W.	49		Father Point,	S.W. 33
	Yankton,	N.W.	35		Kingston,	S.	30		Gr'nd Haven	W. 32
3.3	Breckenridge	N.	28		Port Dover,	S.W.	40		Kingston,	S.W. 34
	Burlington,	S.	26		Toledo,	S.W.	40		Quebec,	S.W. 47
	Cairo.	W.	28		Toronto,	W.	40		Saugeen,	S.W. 28
	Davenport,	W.	28		Washington,	S.	28	5.1	Quebec,	S.W. 46
	Galveston,	N.	36	4.2	Alpena,	N.	27			

On the 1st of December the only winds which rose as high as 25 miles per hour were from the southeast, and they apparently resulted from a high pressure in New England (30·77 inches) combined with low pressure in Nebraska (29·68 inches). On this day very little rain fell; the greatest being at Milwaukee ·55 inch, and Dubuque ·35 inch. Dec. 2d the force of the easterly winds diminished, while the winds from the south and southwest increased in force. The high winds at Davenport and Grand Haven apparently resulted from a local disturbance in that vicinity. The greatest rain was at LaCrosse, ·61 inch, Leavenworth ·57 inch, and Grand Haven ·41 inch. Dec. 3d the south winds were strong on the front side of the

storm, while the westerly winds on the rear were still stronger, and on this day the rain-fall was very great, viz: at Indianapolis 3·46 inches; St. Louis 2·60; Cincinnati 2·47; Louisville 2·30; Toledo 1·93; Nashville 1·90; Detroit 1·58; Cairo 1·22; Davenport 1·11, and Chicago 1·02.

Dec. 4th, at the time of the morning observation, the winds were similar to what they had been on the preceding day, and considerable rain-fall was reported; but after the morning observation the rain everywhere ceased almost entirely and the south winds on the front of the low center had mostly disappeared, and were succeeded by winds from the west or southwest. At 4.35 P. M. only one case of high wind from the south was reported, viz: at Toledo, and there is reason for believing that this observation was an error, or that it represented only a temporary veering of the wind, for at no other place within a distance of 500 miles was the wind reported from the south. It will be observed that after Dec. 1st, on the front side of the storm there was no strong wind from any easterly quarter; and the strong winds from the south ceased at about the same time as the rain ceased; while the westerly winds continued to blow with unabated force for 24 hours longer. After midnight of Dec. 3d the westerly winds encroached rapidly upon the south winds; and by the afternoon of the 4th had almost entirely supplanted them. This example seems to show that the diminution of pressure in front of a great storm is caused by a warm wind containing a large amount of vapor, and that the increase of pressure in the rear of the storm is caused by a colder wind containing a less amount of vapor; and that when the former winds are the strongest, there is an abundant rain-fall, and the pressure at the center of the low area diminishes; but when the latter winds are the strongest, the rain-fall declines and the pressure at the center of the low area increases.

In order to prosecute these enquiries under different geographical influences, I have prepared a catalogue showing the principal rain-falls in Europe for a series of years, but am compelled to defer its publication until my next article.

Since the publication of my paper on the mean annual rain-fall for different countries of the globe, I have received a considerable number of letters communicating rain-fall observations. As, however, I am hoping to obtain further observations, I shall defer a little longer the publication of the materials already received. Meanwhile if any meteorologist has information which would be useful in preparing a revised edition of my rain-chart, he is respectfully solicited to furnish me a copy of the observations.

ART. II.—*The Phenomena of Metalliferous Vein-formation now in progress at Sulphur Bank, California;* by JOSEPH LECONTE, Professor of Geology, and W. B. RISING, Professor of Chemistry, University of California.

THE attention of geologists has been already called by Mr. Phillips* and Mr. Rolland† to the fact that metalliferous veins are even now forming at Steamboat Springs, in Nevada, and at Sulphur Bank and other places in California; but the observations heretofore made at these places have been of a very general character, and a more careful examination seems still a desideratum. Believing that any additional light, however small, on so interesting a subject would be welcomed by chemists and geologists, we have made repeated visits to Sulphur Bank, viz: in 1877, 1878, 1879, 1880 and 1881, and spent several days each time in examining the phenomena as they occur there. In the meantime the mines which, during our earlier visits, were mere open surface excavations, have been recently developed in a systematic way, thus affording us opportunities of study which have not been enjoyed by any previous observers. The observations made on the ground have been ever since the subject of continued thought, but the phenomena are so complex that we desire this communication to be considered only as a preliminary discussion. We hope, if possible, to continue the investigation.

Some general description of the Coast ranges and of the Sulphur Bank region will be necessary to make the subject clear.

Coast ranges.—The Coast chain of California is a very complex system of ranges with narrow valleys between, contrasting strongly in this respect with the grand simplicity of structure characteristic of the Sierra Nevada. The Cretaceous and Tertiary strata of which it is composed are strongly folded into repeated anticlines and synclines by the lateral pressure which produced the ranges.‡ As shown by the age of the newest crumpled strata which enter into its composition, its birth-time was the end of the Miocene. In some places the strata are unchanged and full of fossils, but in others they are intersected by dikes and overflowed by lava, and are therefore highly metamorphic. This is especially true of the region to the north of the Bay of San Francisco. The high mountain

* Phil. Mag., xlii, 401, 1871. Quar. Journ. Geol. Soc., xxxv, 390, 1879.

† Ann. des Mines, xiv, 384, 1878. It is proper here to remark that our first visit in 1877 was made, and many of the conclusions hereinafter detailed, were given in a verbal communication to the chemical section of the Cal. Acad. of Science before the visit of M. Rolland.

‡ This Journal, xi, 287, 1876.

ridges enclosing the upper part of Napa valley and the mountainous region about the head of the valley are composed wholly of eruptive rocks. The culminating point of former igneous activity, as of elevation in this vicinity, is Mt. St. Helena, an ancient volcano 4,343 feet high; but the evidences of former igneous activity continue northward with little abatement to and beyond Clear Lake. In all this region the country rock is largely overlaid with lava, and feeble secondary volcanic activity still continues in the form of hot springs, carbonated springs, solfataras and fumaroles, or so-called geysers.* In all this region are also found extensive exposures of serpentine, and usually, in connection with the serpentine, cinnabar. The origin of this serpentine is an exceedingly interesting question, but one which we are not now prepared to discuss, for immediately about Sulphur Bank the cinnabar is not associated with serpentine, and it is with cinnabar that we are now concerned.

Clear Lake vicinity.—Clear Lake is a large irregular sheet of water about 25 miles long, 5 to 8 miles wide, and 1320 feet above sea level, situated about 90 miles north of San Francisco and 40 miles from the sea, in the midst of a very rugged portion of the coast chain. The stratigraphic geology of the region has not been carefully studied. The strata, where exposed to view, consist of sandstones and shales much disturbed and almost destitute of fossils; but according to Whitney† they are probably of Cretaceous age. Through these have come up volcanic outbursts, flooding the country and largely covering the strata. Volcanic peaks, some of them with distinct craters, surround the lake on every side, plainly showing that in comparatively late geological times the lake was belted about with a fiery girdle of active volcanoes. The loftiest of these is "Uncle Sam," the summit of which is 4200 feet above sea level.‡ Lava-flows from these volcanoes ran down to the lake margin and into the lake waters, and form now the promontories and islands which diversify its surface. Volcanic activity has now died away into feeble secondary remnants, as hot springs, carbonated springs, solfataras and borax springs, all of which are numerous in and about the lake. The waters from the last have accumulated to form two small borax lakes, or rather pools, near the margin of the greater lake. At one time a considerable quantity of borax was collected as crystals from the mud at the bottom of these pools.

* The geysers of California are not true geysers or eruptive springs depositing silica, but rather fumaroles or smoking solfataras.

† Geol. Surv. of Cal., vol. i, pp. 94 and 100.

‡ "Uncle Sam" is mentioned by Whitney, vol. i, p. 97, as probably metamorphic, but careful examination shows that it is wholly volcanic.

The *time* of the volcanic activity is uncertain but cannot be earlier than the beginning of the Pliocene, for this is the date of the formation of the Coast chain. It is probable that it commenced with the formation of these mountains at the beginning of the Pliocene and may have continued to a much later time. In that case it would be contemporaneous with the much greater volcanic activity of the Sierra and Cascade ranges, which seems to have occupied the whole of the Pliocene and perhaps a portion of the Quaternary.* The eruptive rocks in all this region are andesites and trachytes, somewhat strongly contrasted, but no attempt has been made to determine the order, if any, in which the two kinds have been erupted.

The immediate vicinity of Sulphur Bank.—One of the most active centers of vulcanism during Pliocene times and of solfataric action now, is about Sulphur Bank. This place is situated at the extremity of an eastward-extending bay of Clear Lake, and in its immediate neighborhood are distinctly visible four or five low volcanic cones with almost perfect craters, the nearest two being less than a mile distant. The Bank itself is a low, rounded hill, rising from the lake margin and apparently the lakeward extremity of a lava-stream from one of the nearest volcanoes to the east, toward and almost to which it may be easily traced as a low ridge of lava-blocks. The rock which forms this lava-stream, as well as that of the crater from which it apparently flowed, according to Mr. W. Jackson, the instructor in mineralogy and lithology, to whom we referred it, is an augite-andesite.† During all our earlier visits, the mines were simple excavations in this hill, open to the sky, and none more than 50 to 60 feet deep; but when last visited, in 1881, regular mining operations had commenced by sinking a shaft 260 feet deep, and running drifts at various levels. The stratified rock in the vicinity, when not covered with lava and concealed from view, consists of sandstones and shales inclined at high angles.

* This Journal, vol. vii, pp. 167 and 259, 1874.

† Mr. Jackson has given us the following as the result of his examination: "The normal rock is of a grayish black color, massive, perfectly compact, with a slightly vesicular texture that at times becomes very pronounced. The external appearance is so little distinctive that it has been variously called trachyte, basalt and trap. It consists essentially of plagioclase and augite, but magnetite is also freely disseminated through the rock, and orthoclase is not altogether wanting. The plagioclase is in the form of a very minute, lath-like, colorless microlites, among which are densely crowded the still more minute rounded granules of augite. One can also detect, with very high powers, remnants of a colorless glassy base lurking here and there between the granules. All the constituents are free from inclusions with the exception of a magnetite granule in many of the augites. Considering with Rosenbusch, olivine as an essential constituent of basalt (and I see no other way of upholding a distinction between basalt and augite-andesite), the Sulphur Bank rock becomes an augite-andestite. I have already observed the same rock from many different localities in the Pacific coast ranges."

Description of the bank.—At first sight the volcanic origin of the surface rock of the hill is not conspicuous. The bank looks like an immense oval ash-heap, 300 yards wide, 600 yards long and about 100 feet high above the lake level. The surface consists of snow-white, very fine pulverulent material which on analysis is found to be pure silica. It is evidently the residue resulting from complete decomposition of the volcanic rock, as will be explained hereafter. As we go deeper the rock becomes sounder and the mass now seems to consist of andesite blocks rounded by decomposition with the products of decomposition between, and looking much like rounded "bowlders" imbedded in a white ashy or chalky earth. Very often the rounded blocks (so-called bowlders) disintegrate into concentric whitish shells which scale off to a darker sounder rock in the center. These shells are undoubtedly the evidence of an obscure original ball-structure developed by decomposition. In some places an obscure flow-structure is developed in the same way and gives rise to an appearance of horizontal lamination. Between the loosened shells or laminæ, in the earthy mass between the bowlders, and in every crack or crevice of any kind is found sulphur in abundance and often in very beautiful crystals. As we go still deeper, the rock becomes still sounder until it finally assumes its natural square-jointed structure. Cinnabar now begins to appear mingled with the sulphur, and in increasing relative proportions, as we go deeper and deeper. As a general rule therefore, even in this superficial lava-portion of the mines, the sulphur is more abundant near the surface and the cinnabar at greater depth. In fact the sulphur is not found at all below a depth of a few feet. The mines were therefore at first worked wholly at the surface for sulphur only, then for sulphur and cinnabar, and now, since regular mining has commenced, for cinnabar only.

Iron is also very abundant; near the surface as ferric and magnetic oxides staining in places the disintegrated mass and at greater depths as pyrites impregnating the somewhat firmer rock. In many places, scattered irregularly through the disintegrating mass, are found streaks or pockets, or larger areas of a black spongy material consisting of rotten rock colored with magnetic oxide. This material is usually rich in both sulphur and cinnabar. Again: the decomposed material is in many places strongly acid and astringent from the presence of free sulphuric acid and sulphates of alumina and iron. Lastly, bitumen is found every where in very small quantities impregnating the rocks, and detectable as minute black globules under the microscope. It is also found in the assay of the rocks.

As far as yet described the rocks have evidently been

changed by oxidizing agents carried down from above. But when we go still deeper—beyond the influence of atmospheric agencies, though still within the limits of the lava-cap—an entirely different appearance and reaction is observed. The decomposition is now no longer universal, but only in streaks along water-ways; the result of decomposition is no longer white chalky silica, but tough unctuous blue clay, and finally the earthy residuum is no longer acid from down-going acid waters, but alkaline from up-coming alkaline or solfataric waters. In this region and extending a little way above it, irregular cracks and fissures running in all directions are filled with a hydrous silica (opal) in a soft cheesy condition which might easily be mistaken for ozocerite. This half-consolidated gelatinous silica, evidently very recently deposited from the alkaline water, when cut or broken is nearly always found to be streaked and clouded with cinnabar. Here then undoubtedly we have still forming under our eyes, mineral veins with quartz vein-stuff and metallic ore. "The work of nature has been interrupted by the work of the miner." But of this more anon.

Beneath the lava-cap.—Thus far we have confined ourselves within the limits of the lava-cap. The observations of all previous writers have been thus confined, and most of the facts thus far mentioned have been noticed also by others. The facts now about to be mentioned, however, have not been previously described.

At the time of our earlier visits, viz: from 1877 to 1880 inclusive, the underlying country rock was reached and examined only in one place, viz: in the excavation called "the wagon-spring cut."* This, at that time the deepest opening, is situated near the margin of the lava-flow, where the lava is thin, and therefore the stratified country rock is quickly reached and is penetrated thirty or forty feet. The stratified bed-rock consists here of sandstones and shales standing nearly on edge. The opening has followed a soft brecciated stratum, several feet thick, composed of a mere rubble of angular fragments of sandstone and shale with mud of bluish clay between. On either side of this rubble-mud stratum is firmer rock; on one side sandstone and on the other shale. The mud is hot and at the bottom of the cut, hot alkaline waters highly charged with sulphydric, carbonic and boracic acids, are seen to bubble up freely. The rubble-mud stratum is evidently a water-way for the up-coming of hot water containing alkaline sulphides with excess of sulphydric and carbonic acids (solfataric waters). This rubble-mud stratum is rich in cinnabar, though in invisible

* The underlying strata had been previously reached in two other places, viz: the "Bath-house cut" and the "Parrott shaft;" but these openings had been abandoned and at the time of our visits were filled with hot water.

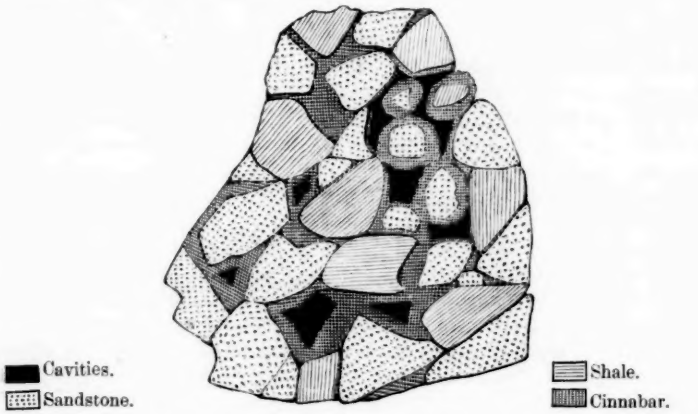
particles. Pyrites is also found in notable quantities both in the rubble-mud and in the bounding rocks on each side, especially in the more porous sandstone. The same rubble stratum can be traced out-cropping on the surface farther east beyond the limits of the lava-flow, and is there also the seat of solfataric action, and has been worked for cinnabar. The question of the origin of this rubble-mud stratum will come up for discussion hereafter.

Completer examination of the strata beneath the lava.—The above is a brief description of the phenomena as seen during our earlier visits. In the summer of 1881, we again visited the mines, and in addition to complete confirmation of previous results, had an opportunity, never enjoyed before, of examining the stratified rocks underlying the lava to a depth of 260 feet. Since our previous visit in 1880, the very intelligent Superintendent, Mr. Fiedler, had sunk a shaft some distance to the south of the "Wagon-spring cut," and about 150 feet outside the limits of the lava-flow, with the intention of reaching the vein by drifting under the lava on several different levels. The upper one of these drifts, viz: the 210-feet level, had already been pushed 150 feet in the direction of the "Wagon-spring cut," but had not yet quite reached a point directly beneath it. The phenomena observed are as follows: for 70 or 80 feet from the shaft the rock is barren sandstone and shale dipping to the south and comparatively dry and cool. Then the rock becomes shattered or brecciated and highly charged with up-coming hot water containing large amount of alkaline sulphides, with excess of CO_2 and H_2S. In the hottest places the temperature of the water is 160° and the CO_2 bubbles up so profusely that a lighted candle near its surface is quickly extinguished. The heat of the freshly cut rock is often too great to be borne by the naked hand. In this hot shattered rock is found the ore. The mine is worked with difficulty on account of the almost insupportable heat. This difficulty has now been largely removed by the more complete ventilation subsequently introduced. The lower-level drift had not at the time of our visit yet reached the ore-body.*

Description of the ore-bodies.—The brecciated layer which forms the water-way, is here, as in the wagon-spring cut, composed of fragments of sandstone and shale, mostly angular but sometimes sub-angular, as if the edges had been either worn away or else dissolved away. In some places, where the up-

* Since our last visit we understand from Mr. Fiedler that the work is now progressing on five different levels, viz: 104 feet, 157 feet, 210 feet, 260 feet and 310 feet. The third level, 210 feet, has been pushed 232 feet, cutting through the ore-body and reaching only barren rock on the other side. The fourth level has been pushed 136 feet and has reached the ore-body. The varying dip on these different levels show that the strata are very much broken up.

coming water is abundant, there is only hot mud between the fragments, but in other places where the rock is drier and the solfataric action finished, the fragments are firmly cemented with a paste of consolidated mud containing disseminated metallic sulphides, or often wholly with deposits from the solfataric waters; and thus the vein becomes a mere breccia united by a paste of cinnabar, pyrites and silica, but mostly cinnabar. The spaces between the fragments are sometimes entirely filled with deposit, sometimes only partially filled, leaving hollow spaces between. In this case the mass may have the appearance of an aggregation of round pellets of cinnabar, but on breaking these pellets they are found to have an angular fragment of rock as a nucleus. The deposits lining or filling the cavities are most commonly cinnabar, but sometimes pyrites, or silica, or all of these in alternate layers. The silica was found in all stages of consolidation,—sometimes chalcedonic, sometimes cheesy, and sometimes gelatinous.* The accompanying figure, roughly drawn from a specimen in our possession, will give a general idea of the appearance of the richer portions of the ore-body.



The vein (if such it may be called) is largely in the brecciated stratum already described, but is apparently not wholly confined to it. It is extremely irregular, sometimes widening out to many yards, then thinning down to a few inches or even pinching out and disappearing entirely, to reappear again

* A similar gelatinous condition of silica has been frequently observed by one of us in the hydraulic gravel mines, usually in connection with decaying drift-wood. It is often colored yellowish by oxide of iron and in color and appearance so exactly resembles the protoplasmic mass of some lower forms of vegetation, as to completely deceive all but the most careful observer.

in a different stratum; sometimes repeated several times with barren rock between; sometimes leaving the brecciated layer and appearing in the shattered sandstone on one side or the other. In some places it is extremely rich—a mere breccia with cinnabar paste—often the cinnabar constituting more than one-half the weight of the whole. No free sulphur was found at this depth nor in the wagon-spring cut; nor indeed at any depth greater than a few yards below the surface.

The origin of the brecciated layer is an interesting question. During our last visit we found, outcropping in several places near the lake margin, farther to the southwest, beyond the limits of the solfataric action and striking in the direction of the Bank, an ordinary brecciated stratum consisting of angular fragments of sandstone and shale united by a stony paste. This is probably the same as the rubble-mud stratum of the Wagon spring cut, only in this case the stony paste has not been reduced to mud by solfataric action. It is also probably the same as, or similar to, the brecciated ore-bearing stratum of the underground works, only in this case the paste has not been replaced by deposits from the solfataric waters. This therefore seems to represent the original condition of the ore-bearing stratum. It seems probable therefore that there was here a brecciated stratum (or perhaps several such) conformable with the other strata of sandstone and shales and tilted along with these in the process of mountain formation; and that being a plane of weakness, this stratum was loosened and shattered by repeated subsequent back-and-forth crust movements connected with the volcanic eruptions, and thus became a way for ascending solfataric waters. But the extreme irregularity of the ore-bearing fissures shows that the loosening and shattering was not wholly confined to the brecciated layer, but especially where the inclination of the strata was not very high, passed from stratum to stratum, following now one now another in an uncertain way. Through all this shattered rock, whether in the original brecciated layer, or in the sandstones and shales on either side, the solfataric waters came up and deposited and is still depositing its freight of silica and metallic sulphides.

Explanation of the phenomena.—The ridge of lava which terminates in Sulphur Bank may be a stream from one of the nearest volcanos, to which it can be almost continuously traced; or it may be the remains of a very viscous eruption coming up through a fissure and spreading but little; and thus simulating a lava stream. We have assumed the former as by far the more probable, because it can be traced almost continuously to a neighboring crater, the rock of which is identical with that of Sulphur Bank, but the question can be definitely settled only by continuing the tunnels beneath the lava cap

and ascertaining whether or not a dike is cut through. If the lava cap is a stream from a neighboring volcano, as seems almost certain, then its presence here has nothing to do with the solfataric action or the occurrence of cinnabar. These originate far beneath the lava and would come to the surface, all the same, if there had been no stream in this place or if it had not reached so far. Rolland thinks the solfataric action preceded the volcanism—that the lava stream flowed over and covered *pre-existing* solfataric vents and thus compelled the waters to seek the surface through their jointed structure. This may or may not be true of this particular stream, but is probably *not* true of the volcanic activity of this vicinity. Solfataric action usually *follows* rather than precedes eruptive activity. We suppose therefore that with the decline of Pliocene volcanic activity of this vicinity, the solfataric action commenced, and that the solfataric waters coming up through somewhat definite channels in the tilted strata, but finding itself beneath the lava cap, spread in all directions through its open jointed structure and so reached the surface, depositing more diffusely and therefore in less available form in this surface portion. The same open joint structure has given freer access to air, and therefore produced a more decided surface action, as will be explained below.

Again: There are evidently here two very different and even opposite kinds of chemical action going on; the one *primary* and deeper seated produced by up-coming alkaline subterranean waters, the other *secondary* and superficial, produced by the acid down-going surface waters. This latter is greatly facilitated by the open joint structure of the lava. We wish now to give a general explanation of the action of these two kinds of water, and the mode of formation of the different kinds of products previously mentioned.

Action of the up-coming subterranean water.—(a.) *Clay and Silica.* The ascending waters, by analysis, contain a large amount of sulphides and carbonates of sodium and ammonium with excess of carbonic and sulphydric acid. They also contain a considerable amount of boracic acid. These waters, coming up from unknown depth and at high temperature, dissolve the silica from the rocks and carry it upward on their way in solution, while the rocks thus leached of their excess of silica are left in the water-ways as a tough, unctuous clay—colored bluish by protoxide of iron. The silica thus gathered below and carried upward in solution is again deposited by cooling and relief of pressure in fissures and cracks first as gelatinous silica which then gradually by loss of water becomes cheesy and finally chalcedonic.

(b.) *Cinnabar.* The same alkaline sulphide waters must have

held in solution also metallic sulphides, especially mercuric sulphide: for these are found associated with the silica in such wise that the two must have been deposited from the same solution. Sometimes the cinnabar is embedded in the silica, and visible on cutting or breaking as reddish cloudings and streakings, sometimes alternating with silica in successive layers lining cavities and fissures, and sometimes alone lining or filling such cavities and fissures. The solvent of the cinnabar seems undoubtedly to have been alkaline sulphides. There has been it is true, much difference of statement among the best chemists as to the solubility of most metallic sulphides in alkaline sulphides, but recent experiments have made probable at least a feeble solubility, and the most recent and reliable of all, viz: those of Mr. Christy* in which cinnabar was subjected to the prolonged action of alkaline sulphide solutions, exactly imitating the composition of the solfataric waters of California, under heavy pressure and super heat, has placed the solubility under these conditions beyond all reasonable doubt. Whatever be the solvent, it is evident that cooling, relief of pressure and perhaps escape of H_2S and CO_2 in the ascending waters would diminish solubility and produce deposits in the water-ways.

(c.) *Pyrites.* The pyrites found disseminated in the rocks at all depths yet reached may (1) have been brought up from below in solution in the solfataric waters and deposited like the cinnabar, or (2) may have been formed by reaction of alkaline sulphides on iron-silicates of the rocks, especially the lavas, as suggested by Bunsen, in the rocks of Iceland, or finally (3) may have been formed by deoxidation of iron sulphate by organic matter, as we so often see elsewhere. That the first method is the true one in many cases—that the iron sulphide was held in solution and deposited like the cinnabar—is proved not only by the fact that it occurs abundantly beneath the lava in pure sandstones free from other forms of iron, but also by the fact that it is found alternating with silica and cinnabar in successive layers, lining cavities, in such wise that it must have been deposited from the same solution. It may have been deposited also in the other ways, but this one seems certain.†

(d.) *Sulphur.* Sulphur is well known to deposit freely from all springs containing excess of sulphydric acid. By contact with the oxygen of the air the hydrogen of this gas is oxidized and the sulphur deposited. Hence the deposit of sulphur is always very superficial and quickly gives place to metallic sulphides as we go below the influence of the air.

Thus far we have spoken only of the deposits from the up-

* This Journal, xvii, 450, 1879.

† Phillips also found it imbedded like cinnabar in recently deposited silica.

coming subterranean waters. We now come to speak of the action of the down-going surface waters. The deposit of sulphur last spoken of forms the transition between the two, since it requires the presence of air.

Action of descending surface waters. (a) *The sulphuric acid* is, of course, formed by the more complete oxidation of the sulphydric acid gas, the result of more complete contact with air. In fact this takes place mainly in the air, and the effect of prevailing dry winds in carrying it in particular directions is plainly seen. Sulphuric acid is however also formed as a secondary product in the oxidation of pyrites. (b) *Iron Sulphate* is first formed by oxidation of pyrites and then by further oxidation runs down to (c) *ferric and magnetic oxide*, giving up its sulphuric acid. The sulphuric acid thus formed either by direct oxidation of H_2S, or set free from iron sulphate by oxidation of the latter, attacks the iron and alumina, in fact all the bases of the volcanic rock forming iron sulphate and (d) *alumina sulphate*, and leaves the rock as (e) a *snow-white powdery mass of pure silica.*

These surface effects of solfataric waters are seen in many places in the Clear Lake region as, for example, at Chalk Mountain, several miles north of Sulphur Bank, and elsewhere. Somewhat similar effects have been observed also in other parts of the world where solfataric springs occur. But the deeper effects have been less observed and are therefore of the highest interest.

We have attributed the deposit of metallic sulphides and of silica, to cooling and relief of pressure and, possibly, escape of H_2S. Doubtless these are the main causes of decrease of solvent power and therefore of deposit. But it is probable also that at a certain line where the up-coming alkaline meet the down-going acid waters, the deposit is completed by neutralization. Thus the line of demarkation between the two kinds of reaction is sharper than it would otherwise be.

It will be observed that in the present article we have confined ourselves wholly to the description of phenomena and to such immediate explanation as is forced on the observer. We have not attempted any discussion of the bearing of these facts upon the general theory of metalliferous vein formation. This is reserved for a possible future paper in case our investigations justify it.

ART. III.—*Modes of occurrence of the Diamond in Brazil;* by ORVILLE A. DERBY.

THE diamond washings of the vicinity of the city of Diamantina, in the province of Minas Geraes, afford examples of several modes of occurrence of the diamond, which, so far as known at present, may be taken as types of all the washings of the empire.

The diamond region of Diamantina is situated along the crest and on both flanks of the Serra do Espinhaço, the great interior mountain range of Brazil which divides the waters of the São Francisco from those of the Doce, Jequetinhonha and other rivers. The general height of the watershed in this region is about thirteen hundred meters above the level of the sea or about five hundred meters above the general level of the elevated plains of the São Francisco valley, lying immediately to the westward. The prolongation of this range to the northward includes the diamond region of Grão Mogol in the province of Minas Geraes and that of the so-called Chapada Diamantina in the neighboring province of Bahia.

The general geological structure of this region is represented in the following section based on the observations made in three journeys by different routes between the river São Francisco and Jequetinhonha.

A, River São Francisco. B, Gurvea. C, Heights of Guinda. D, Diamantina. E, Heights of Curralinho. F, River Jequetinhonha.

a—White gneiss exposed in a long narrow zone running N.–S., to the southwest of Diamantina near the village of Gurvea. In the journey made farther to the northward going directly west from Diamantina this series did not appear.
b—Series of hydromica schists, schistose granular quartzites (itacolumites) and itabirites. *c*—Series of granular quartzites passing at times to conglomerate. *d*—Series of argillaceous shales and slates, limestones and sandstones. *e*—Horizontal shales and sandstones.

The point in which this section differs most materially from the descriptions of the region hitherto published is the separation of the upper quartzite (*c*) as a distinct formation, unconformable to the series containing the itacolumites or lower quartzites, with which it has generally been confounded. This confusion is easily explained by the fact that most travelers have confined their observations to the eastern side of the watershed where, owing to the two quartzites having the same

strike and the same easterly dip, the unconformability of stratification is not very apparent and the close lithological resemblance of the two rocks throws one off his guard in regard to it. Having recognized the unconformability of these beds on the western slope of the range where in places the dip is in opposite directions, I took pains to look for it elsewhere and found many evidences of it on the eastern side as well.

The junction of the two quartzites is in many places specially interesting. The schistose beds of the lower quartzite enter tooth-like into the mass of the upper, and the two former are apparently homogeneous rock in which only the closest scrutiny can detect the line of junction, indicated by a few scattered pebbles or a very slight difference in the intimate structure of the beds. Away from the line of junction this discrimination of the two series is more difficult and, if no pebbles can be found in the rock, is often impossible, so close is the resemblance between the finer portions of the upper quartzite, and the lower to which I would to restrict the name of itacolumite.*

The relations of series *c* and *d* have not been clearly worked out as the two have not been seen in contact, and it is possible that they should be united. The differences in the lithological characters of the rock and in their distribution is, however, against this view. The limestone of series *d* is the only rock of the region that has afforded fossils. At Bom Jesus da Lapa, on the São Francisco, some distance to the northward I found specimens of the corals *Favosites* and *Chætetes* which indicate Silurian or Devonian age. Liais reported fossil cirripeds of the genus *Pollicipes* in the same limestone at Lapa do Urubú on the Rio das Velhas, but at this locality I only found plates of white calcite which might be mistaken for fossils. The fossil oyster of the same author from the sandstone of the Abacté (series *e*) appears to be based on structure lines in the rock. I failed to find any evidence in support of his view of the Secondary age of these rocks, and on the contrary have direct evidence in opposition.

These preliminaries are necessary for a correct appreciation of the phenomena presented in the various washings which will now be described. The miners established a distinction, which it is convenient to retain, between river washings (*servicos do rio*) and prairie washings (*servicos do campo*). Of the former the most famous are in the bed of the Jequetinhonha where I had an opportunity of examining three, the only ones that have been worked of late years.

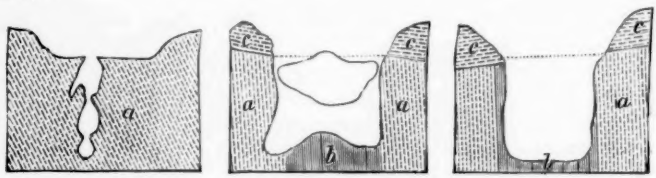
These mines are situated to the eastward and southeastward

* Both series occur in the Serra do Itacolumi at Ouro Preto from which the rock takes its name. It is only the lower one however that affords, and that rarely, the flexible variety to which the name is more particularly applied.

of Diamantina at distances of from 6 to 15 miles from the city and three or four miles from each other along the course of the river. The upper one, the Canteiro, is situated a mile or two below the bridge on the road to the provincial capital. The Santo Antonio mine is a little above and the Acaba-Mundo a little below the confluence of the Jequetinhonha with its equally famous tributary, Ribeirão do Inferno. The Jequetinhonha is here a wild mountain torrent flowing in an exceedingly rugged and picturesque narrow gorge. The river had been turned for short distances by means of temporary dams and wooden sluices and the sand and gravel had been removed from those parts of the bed thus exposed which were known or supposed to be unworked.

The rocky river-bed was found to be excavated in a most remarkable manner to a depth of 75 to 100 feet below the normal bed, presenting what may be called subterranean cañons filled with fallen rocks, sand and gravel up to the natural level of the rocky and sandy bed. These cañons had served as natural launders in which at some time rich diamond-bearing gravel had been deposited. Some of them had been more or less thoroughly cleaned out by former workings and of course refilled immediately when the river took possession of its bed. This newly deposited gravel is not considered worth washing, although it contains some diamonds, and in fact since diamond-washing commenced in the river the newly formed deposits consist of material that has already been more or less thoroughly washed.

Each of these submerged cañons presents some peculiar features dependent on the character of the beds and the relation of the river to them. A diagramatic section of each is given below.



Canteiro. Santo Antonio. Acaba-Mundo.

a—Lower quartzite (itacolumite). *b*—Schists. *c*—Upper quartzite.

At the Canteiro mine the river runs N. 25° E. along the strike of a series of beds of the lower quartzite, dipping 60° to the eastward. The cañon, several hundred metres long, is formed of a line of pot-holes which are generally confluent below the surface so as to form a nearly continuous underground channel. Some of the pot-holes widen out to three or four metres but in general they are much narrower. Some are

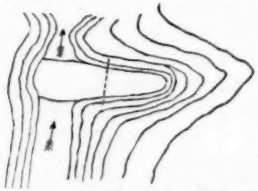
regular from top to bottom, while others present constrictions as represented in the diagram. The upper levels of these pot-holes had been worked out by former owners and were found filled with new unproductive gravel but in the lower levels rich virgin gravel was found.

At Santo Antonio the cañon occupies the whole width of the river-bed and has even widened out below so that the walls are overhanging. The river has here cut through the upper quartzite so as to meet the junction of the two series at about the present natural level of the river-bed. Flowing along the strike of the lower series, it has encountered the thin layer of softer beds of schists and schistose quartzites which form the floor of the cavern, enclosed between the more massive beds which form the walls. The cañon which is about 100 feet deep was filled with fallen masses of rock and gravel which had been removed at the two extremities of the working, but a large rock tightly wedged in between the walls, and which had formed a small fall in the river, had been left, and shored up by stout wooden braces, while work was being carried on underneath by the light of torches.

The Acaba-Mundo cañon is similar in many respects to that of Santo Antonio, but is remarkable in being transverse to the bed of the river which it cuts completely across. The position of the beds is here approximately as follows:

Upper quartzite, strike N. 40° W., dip 15° S.W.
Lower " " N. 20° W., " 80° E.N.E.

This extraordinary *cul-de-sac* cut nearly 100 feet below the natural river-bed, which is here quite shallow, appears at first sight to be an old river channel. That this is not the case is proved by the fact that on the right side (where it was open to examination) it abuts against a hill, as is shown in the accompanying plan. The small stream which, flowing from this hill, falls into the head of the *cul-de-sac* is too insignificant to have excavated this channel as wide as that of the main river which above and below the cut has exercised but little excavating power. The true explanation of its formation is to be found in the fact that the river here flows across the strike of the lower beds and that, having cut the compact upper beds, it found a soft bed of schist cutting across its course and enclosed between two harder beds. The soft bed now forms the soft clayey bottom of the cañon, and though decomposed still shows its schistose character. The constric-



Plan of the river bed at Acaba-Mundo. The dotted line shows the position of the cross section.

tion in the river just below would naturally form a back-water with eddies at this point. The small stream mentioned may have facilitated the process by cutting a narrow channel through the upper quartzite, and thus admitting the river to undermine it by the excavation of the softer bed below. The cañon was filled with fallen blocks, and with sand and gravel. The latter, having been introduced since a former working a number of years ago, was unproductive. It was on the supposition that the former cleaning out had been incomplete that work was undertaken again, but as the event proved only unimportant remnants of the original gravel were met with.

The gravel of the Jequetinhonha is very varied. Professor Gorceix gives a partial list of 28 minerals, which he has recognized among the finer and heavier pebbles which the miners distinguish under the name of *diamond formation*, and which they consider as indicative of the presence of the gem, and notes the abundance of quartz, the oxides of iron and of titanium, tourmalines, and the presence of chlorophosphates (Comptes Rendus, No. 25, 1881). The coarser material of the gravel is evidently derived from the rocks of the two series through which the river flows at the mines and has not been transported very far. The finer material including many rare minerals with the diamond may have come from greater distances, either from the main river, or its tributaries, but there is a strong presumption in favor of the view that this also has been derived from one or the other or both of the two series. Having followed the river for nearly the whole of its course between the Acaba-Mundo mine and its source, and having crossed the upper valley along several lines, I have never seen any evidence of the existence of any other series from which the gravel can be supposed to be derived. It should be mentioned that at many points along the river the upper series presents a conglomerate character.

Of the *servicos do compo* some of the most extensive are situated on the high ridge between Diamantina and the Jequetinhonha, known as the Heights of Curralinho. Of these the most interesting are those of Bom Successo and Boa Vista which almost overlook that of Acaba-Mundo. The heights of Curralinho are capped by a heavy mass of coarse bowlder conglomerate belonging to the upper quartzite series. Bom Successo and Boa Vista are situated on opposite sides of a small valley at the northern extremity of the conglomerate ridge and the material washed is the disintegrated conglomerate, parts of which have been redistributed by water while other parts have never been disturbed.

A similar mode of occurrence is seen on the high ridge to the southwestward of Diamantina at Guinda and Sopa. These

localities are on opposite sides of a high rounded ridge forming the divide between the Jequetinhonha and the Rio Pardo, an affluent of the Rio das Velhas. This ridge is composed for the most part of schists and quartzites of the lower series, with occasional outliers of the upper series. At the Sopa mine a deep excavation near the top of the ridge shows at the top a layer of red soil with a thin bed of gravel beneath; then a thick layer of reddish sand with scattered pebbles which passes into a coarse gravel containing pebbles of various kinds and bowlders of quartzite and schists. The bottom of the excavation is formed by decomposed schists and schistose quartzite in highly inclined beds traversed by veins of lithomarge and smoky quartz. These beds present an irregular surface which is evened up by the sand and gravel deposit.

There is a marked difference between the upper and lower diamantiferous gravel beds of this place which though hard to define has been recognized by the miners who give a special name, *Sopa* (soup), to the lower gravel. I take the upper bed to be the usual superficial and modern gravel deposit due to sub-aerial denudation, and the lower one to be a decomposed conglomerate, belonging to the upper quartzite series. At the neighboring locality of Guinda the conglomerate character of the deposit is even more apparent, and I am convinced that both of these deposits can with safety be referred to the same category as those of Bom Successo and Boa Vista.

About 100 miles to the northward of Diamantina on a stream called Corrego dos Bois near the city of Grão Mogol, there is a famous locality where the diamond has been mined in a solid rock which has always been classed as itacolumite. Neither Claussen von Helmreichen, nor Heusser and Claraz, who visited this locality, recognized the distinction between the upper and lower quartzites, and their descriptions therefore leave one in doubt as to which series the diamond-bearing rock should be referred. The rock is described as a compact itacolumite enclosing rounded concretionary masses of the same character as the gangue, in which they are embedded, and which are well described by the miners' name of "pigeon eggs."

The presence of these masses led von Helmreichen to consider the view, which he ultimately rejected, that this was a regenerated rock, that is, a conglomerate. I have elsewhere (Archivos do Museu Nacional, vol. v), maintained the opinion that these masses are true rolled pebbles, and that this rock belongs to the upper quartzite series.

The conglomerate character of the diamond-bearing rock has now been clearly established by Professor Gorceix who was so fortunate as to obtain at Diamantina a specimen showing a rolled pebble of hyaline quartz alongside of an embedded

diamond (Comptes Rendus, No. 25, 1881). Professor Gorceix considers, however, that this rock may possibly belong to the lower series since conglomerates with pebbles of hyaline quartz have recently been discovered in that series as well. In von Helmreichen's complete memoir, which I have only recently seen, there is a sketch of the locality which shows conclusively that both quartzites occur at the Corrego dos Bois, and that the diamonds are found in the upper one just above the line of junction of the two series. This sketch is interesting also as showing how close must be the resemblance of the two rocks to have led so able a geologist (as von Eschwege also, in other places) to overlook such unmistakable evidence of the existence of two unconformable series.

In the four localities of Bom Successo, Guinda, Sopa and Grão Mogol the diamond occurs with rolled pebbles derived from older rocks and must itself be regarded as a pebble in its secondary deposit. In many other *servicos do campo* it occurs in gravel deposits that are clearly of modern origin. The facts above presented proving the existence in this region of a conglomerate formation or of a quartzite containing scattered pebbles which has suffered extensive denudation, will explain the origin of these deposits without recourse to theories of glaciation or of former systems of drainage different from the present ones. I may mention here by way of parenthesis that in many other parts of Brazil, where anomalous gravel deposits occur that in northern latitudes would be set down without hesitation as of glacial origin, I have recognized the presence of pebble-bearing formations. In other washings the gravel consists of angular fragments of vein quartz left on the surface by the wearing down of the soft beds traversed by the veins. In these cases the matrix of the diamond must be near at hand, but so far as I am aware it has never been sought for.

By far the most interesting of the *servicos do campo* is that of São João da Chapada, situated some twelve miles to the west of Diamantina on a high rounded ridge lying between the Caethémirim, a famous affluent of the Jequetinhonha, and a stream flowing to the Rio das Velhas. The singular feature of this mine is the occurrence of the diamond in clay or earth (*barro*). It has been examined and described by Heusser and Claraz, von Tschudi and Burton, but its true character was first pointed out by myself (Archivos do Museu Nacional, vol. v, 1881), and by Gorceix (Comptes Rendus, No. 25, 1881).

Two mines, the Barro (clay) and the Duro (hard), opened on opposite sides of the ridge, have been worked until they met at the center producing an excavation several hundred meters long and some twenty or more meters deep which closely resembles a railroad cutting the sloping sides of this cut show

a layer of red soil above, with some coarse ferruginous gravel at the base, resting on soapy parti-colored clays. The disposition of these clays is much obscured by slides, but in a number of places it may be seen that they result from the decomposition *in situ* of unctuous (hydromica) schists underlying a bed of itacolumite which is well exposed at the entrance of the Barro mine. This bed strikes N. 5° W. and dips 40° E. The direction of the cut is approximately N.–S., showing that the diamond-bearing material has been followed along the strike of the beds.

The diamond-bearing clays are found in layers up to 1½ meters in thickness intercalated in the midst of the barren clays. Three distinct layers have been described of which I only saw specimens of two in considerable masses that had been dislocated by slides. One was a soft bluish black mass showing on a fresh fracture thin alternating layers of white clay and black powdery hematite. The second mass consisted of a section of a quartz vein adhering to a mass of reddish mottled earth about half a meter thick. Layers of red decomposed schist adherent on one side to the quartz, and to the earth on the other, prove beyond a doubt that this, as well as the quartz, belongs to a vein. The third layer is described by Professor Gorceix as consisting of lithomarge with crystals of quartz presenting the same aspect as the topaz-bearing lithomarge veins of Ouro Preto.

The reddish earth of the second mass is the diamond-bearing material of that layer. It is evidently a decomposed rock consisting of a clayey and a sandy portion. The sand consists, according to Professor J. W. Mallet, who has kindly examined specimens for me, of quartz grains, microscopic tourmalines, and another black silicate. The clayey portion consists largely of iron. The original character of the rock from which this material is derived can only be guessed at. The only rock known to me in the province which might produce on decomposition such a mixture of quartz, iron and tourmaline is that of the veins of pyrites with quartz and tourmaline of some of the gold mines, notably that of Passagem near Ouro Preto, where the vein occurs under somewhat similar circumstances and in the same geological series. The quartz portion of the São João vein is much splintered and full of brilliant plates of specular iron.

Professor Gorceix states that the diamond-bearing layers or veins accompany the stratification of the enclosing beds, and notes the great similarity of this diamond mine to the topaz mines of the vicinity of Ouro Preto, as well as the marked identity in the minerals which in one place accompany the diamond and in the other the topaz. The most important

minerals obtained by him in washing several tons of material from the different layers were, besides the diamond, anatase, rutile, specular iron, martite, and tourmaline.

In the Diamantina region, therefore, the diamond occurs *in situ* in its original matrix in more or less well-defined veins traversing the hydromica schist and itacolumite formation. It occurs also as a transported pebble in the upper quartzite formation. In the superficial gravel beds of the highlands, it occurs in its second or third place of deposit according as these have been derived from the wearing down of one or the other of the older diamond-bearing series. In many places it is probable that the superficial gravels contain an admixture of diamonds from both these series, and it is certain that this is the case in the river gravels, which may also contain diamonds washed from the superficial gravels and that are therefore in their fourth place of deposit.

If an observation made to me by Mr. Meziel F. de Aguiar, owner of the Sopa mine, be exact, the diamond-bearing veins are persistent over long distances. He stated that a straight line drawn from the São João mine through the Sopa and prolonged to the southward would pass through or near some half dozen of the most noted *campo* washings. Such a line would have a length of about twenty miles, and it corresponds exactly with the general strike of the beds in this region. In fact I noticed at the Sopa mine that the line of strike prolonged would cut the deep excavation of São João which was plainly visible at a distance of four or five miles, I have reason to suspect, from the information given by this intelligent miner, that the true *barro* formation occurs also at the Sopa, though it has never been recognized as such.

Near the river São Francisco there is a rich river washing on the river Jequetahy, which flows over beds of series *e* of the general section which here consist of conglomerates that have probably furnished the diamonds. The same conditions are repeated on the river Abaeté on the opposite side of the valley. The divide between the São Francisco and Upper Parana valleys, which has rich diamond washings on each slope, presents a repetition of the geological features of the Serra do Espinhaço, and so far as can be learned the general geological structure of the diamond fields of the provinces of Bahia, Goyaz, Matto Grosso and Parana is substantially the same as that above described for the central part of the province of Minas Geraes.

ART. IV.—*On the Influence of Time on the Change in the Resistance of the Carbon Disk of Edison's Tasimeter;* by T. C. MENDENHALL, Columbus, O.

[Read, by invitation, at the April meeting of the National Academy.]

ABOUT five years ago Edison announced the discovery of the remarkable property possessed by carbon when prepared in a special manner, in virtue of which its electrical resistance was greatly lessened by subjecting it to an increase of pressure. Among the numerous interesting applications of this discovery which were quickly made, none was more promising or more interesting than the Tasimeter devised by Edison himself. The extreme sensitiveness of the carbon to the slightest changes in pressure gave rise to the hope that the instrument would far exceed in delicacy those previously in use for the detection of minute quantities of heat.

Mr. Edison was a member of the Draper Eclipse Expedition in the summer of 1878, and used his Tasimeter during the total eclipse of July 29 in that year, attempting to measure the heat emitted by the sun's corona. His report to the director, Dr. Henry Draper, was published in the Proceedings of the American Association for the Advancement of Science for the same year. This report shows that the attempt was by no means as successful as could have been desired, the principal obstacle being apparently the difficulty in the adjustment of the Tasimeter so that the galvanometer needle would remain at zero, and to secure its return to that point after it had been deflected. In fact, the zero adjustment was only made by the use of a peculiar shunt of variable resistance ingeniously contrived by Mr. Edison for the purpose.

The writer is not aware of any other systematic attempt to secure quantitative results through its use, and, as far as known, the instrument has been generally regarded as peculiarly inconstant and unreliable in its indications.

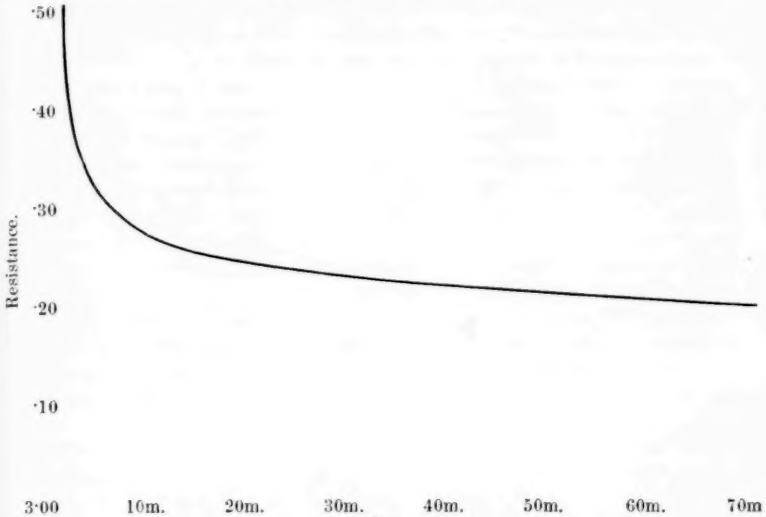
Having in his possession a Tasimeter constructed after the model of that described in the report referred to above, the writer undertook a short time ago to investigate the quantitative relation between pressure and resistance for the carbon disk which belonged to it. In a series of preliminary experiments, the use of the toothed wheel and screw, by means of which the pressure is communicated to the disk, was found to be extremely objectionable on account of the impossibility of exactly reproducing a given pressure. This portion of the instrument was therefore entirely removed, and an arrangement made by means of which any definite pressure might be quickly

brought to bear upon the disk or removed from it. A slender brass rod was placed in a vertical position upon the center of the upper contact piece, the upper end of which rested lightly in a small conical cavity made on the under side of the scale-pan of a balance. The weight was suspended above by a fine thread passing over a pulley, so that by raising or lowering it the pressure was applied or removed as was desired. The carbon disk was made one of the branches of a Wheatstone's Bridge as described by Mr. Edison. In lowering the weight care was taken to make the movement slow enough to avoid any shock to the disk. When the apparatus stood with the weight lifted, the adjustment of the galvanometer to the zero was made without any difficulty, the resistance of the disk appearing to be quite constant. When the pressure was applied, however, the adjustment became very troublesome, and after a few trials it was discovered that *time* was a very important element in the problem. The addition of a pressure of fifty grams reduced the resistance to nearly one fourth of what it was in its normal condition *instantly*, but it was found that the minimum was not reached at once. The resistance continued to fall during the first two or three minutes with considerable rapidity and after that more slowly. A series of experiments was accordingly undertaken for the investigation of this phenomenon. After a number of trials, the bridge was adjusted so that when the key was closed simultaneously with the application of the pressure the needle of the galvanometer would remain momentarily at zero, for the instantaneous effect of this pressure seemed to be quite constant. In a few seconds, however, the needle began to move, showing that the resistance was diminishing. With this constantly decreasing resistance it was, of course, difficult to obtain balances which were very accurate, but generally one could be obtained within a minute after the application of the pressure, and another a minute or two later, and so on. The operation was repeated many times, and a number of points for the curve shown below were obtained, which, though necessarily somewhat scattering, were so situated as to render its general form almost certain. In almost every instance immediately after the removal of the pressure, the normal resistance was again measured, and it was found that while time was necessary for the resistance to reach a minimum after the application of the pressure, the disk seemed to recover its maximum normal resistance instantly upon its removal.

After the construction of the curve showing the relation between time and resistance, and on the supposition that it correctly represents that relation, it was easy to know what the adjustment of the bridge should be at the end of any given time, and thus the difficulty of that adjustment disappeared.

Resistance.

When tested in this way, the curve was found to be correct within the errors of experiment. The following table exhibits the resistances after various times, the *instantaneous* resistance



Curve showing the relation between Resistance and Time.

being called 100. The resistance before the addition of the pressure of 50 grams was 11·67 ohms, which immediately fell to 3·52 ohms upon the application of the weight.

Time in Minutes.	Resistance.	Time in Minutes.	Resistance.
0	100	15	92·9
1	96·6	20	92·5
2	95·4	25	92·3
3	94·9	30	92·1
4	94·5	35	92·0
5	94·2	40	91·8
6	93·9	50	91·5
7	93·7	60	91·2
8	93·6	70	90·9
9	93·4	80	90·8
10	93·3	90	90·7
12	93·1		

It will be seen that the resistance falls a little more than three per cent in one minute, about five per cent in three minutes, and about ten per cent in one and a half hours, and it seems tolerably certain that even then a minimum is not reached. In two or three instances, the time of continuous

pressure was prolonged to twenty-four hours, the resistance at the end being slightly lower than at any previous reading. Finally, the apparatus was left with the weight applied for one week. No measurements were made during that time, but at the end the resistance was found to be decidedly lower than it was at the end of two hours after the application of the pressure, and it is especially to be noticed that on the removal of the pressure the normal resistance of a week before was instantly recovered. In this case the pressure applied was 100 grams. The resistance before the application of the pressure was 11·08 ohms. Upon applying the pressure it immediately fell to 2·34 ohms. In two hours this had been reduced to 2·10 ohms, and at the end of a week it was 1.93 ohms. Thus in two hours it was reduced by about ten per cent, and after one week it was again about ten per cent lower.

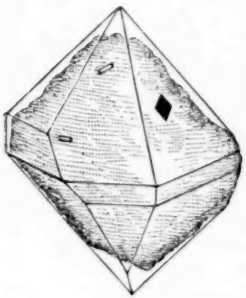
It appears, therefore, that the element of time plays an important part in the phenomena exhibited by the carbon disk, and it seems highly probable that this has been one of the principal causes, if not the chief cause, contributing to the inconstancy and unreliability of the indications of the Tasimeter. The experiments made thus far indicate a fair degree of constancy in its results when this factor is considered. The writer hopes to be able to make further examination concerning the extent to which all of the conditions necessary to its use may be controlled.

The resistance of carbon under pressure has been made the subject of investigations recently by Mr. Herbert Tomlinson and Professor Sylvanus Thompson. The conclusion reached by both is that the diminution of resistance is really due to the contact between the electrodes, and it appears that Professor W. F. Barrett has arrived at a similar conclusion, as a result of experiments made upon a "button of compressed lamp-black." Without knowing anything about the nature of these experiments, the writer desires to record his belief that this theory does not entirely account for the facts stated above. Besides, it seems a little difficult to understand how so small a pressure as fifty grams added to an already existing pressure of about the same amount can increase the area of contact between a flat plate and a flat disk nearly four times, to say nothing of the "recovery" which takes place so promptly upon the removal of the pressure.

ART. V.—*Further observations on the Crystallized Sands of the Potsdam Sandstone of Wisconsin;* by Rev. A. A. YOUNG.

A BRIEF note on the crystallized sands of the Potsdam sandstone quarried at New Lisbon and the St. Peter's sandstone of Wisconsin is published on page 257 of the last volume of this Journal. A fuller account of the observations which I have made is here given.

The quarries near New Lisbon affording the sands described are situated five miles north of the place. The rock is a hard, compact and mainly very fine-grained sandstone. Some slabs carry excellent ripple-marks and fossil tracks. The rock sparkles brilliantly in the sunlight through the reflection from innumerable but minute faces of crystals. When broken up and prepared for the microscope, nearly all the grains show, at least on some part of their surface, a portion of an edge, or face, or an apex of a crystal.



The most finished crystals occur among the minuter grains, some of which are only ·004 in. × ·0035 in. in longer and shorter axes. Much of the sand varies from $\frac{1}{80}$ to $\frac{1}{100}$ of an inch in longer diameter. Some of the small grains are complete in their crystalline form, save at some spot of detachment from a neighboring grain. The simplest form is that of the double six-sided pyramid, but others have portions of the intermediate prism of varying lengths; and besides these are others with modifying planes. A frequent form is roughly pear-shaped, carrying at the smaller end a point of a pyramid, and at the larger a cluster of minuter pyramids. The larger part of the grains have many irregularities of form, whose explanation is obvious when the sand is mounted in balsam.

Accompanying the sand are certain brown kidney-shaped grains, ·003 in. in diameter and smaller, smooth for the most part, which closely resemble certain enclosures that are found in the grains of sand. The rough exterior of part of the grains appears to have sometimes come from the breaking apart of cohering grains. Some of these rough spots occur in the midst of smooth faces, and are shallow six-sided pits with straight sharp edges.

While dry mounting exhibits to the best advantage the crystalline faces, a balsam mounting, or its equivalent, discloses best the interior structure and the mode of origin. Thus

examined the lack of homogeneity becomes apparent at first glance. The crystals—the most complete as well as those least so—are found to inwrap fragments of varying size, contour and structure. When viewed by reflected light, on a dark background, the crystallized exterior is barely discernible as a thin transparent envelope, while the enclosed fragment appears often semi-opaque and has a sharply defined outline.

Generally the longer and shorter diameters of the whole grain accords with those of the enclosed fragment; but in some they are reversed so that the narrowest part of the fragment lies in the line of the greatest length of the grain of sand. Viewed alternately by reflected and transmitted light, one sees apparently two different objects.

The greatest thickness of the crystal envelope which I have yet measured is ·004 in. Ordinarily the maximum thickness—at the extremities of the pyramids—is from ·001 in. to ·0015 inch; but over much of the surface the envelope is so thin as to be but barely appreciable with a power of 150 diameters. In this envelope bubbles or cloudiness are very rare.

The enclosed grains vary much in *contour*. Many are rounded in portions of the outline, though few are symmetrically so. Some are as sharp-angled and jagged as fragments of freshly broken rock. Sometimes their surfaces show by reflected light groovings of a length double or quadruple their breadth, either in single lines or sets of lines, or in lines crossing at varying angles, and in the nuclei of crystals of only ·005 in. in length, as well as in larger. They are furrows rather than scratches, as though the fragment had been rolled with a dragging motion over cutting points. This structure appears also in the nuclei of the crystals of the St. Peter's sandstone. Such facts throw light on the previous history of the individual fragments. These groovings are also finely exhibited in sand, from friable rock of a higher horizon of Potsdam, in which only occasional traces of a crystal envelope appear.

In *structure* the enclosed fragments show great diversity. Homogeneity is the exception. In some a general cloudiness exists, or irregularly scattered bubbles; and in others there are planes or belts of bubbles. Aside from these are other noteworthy enclosures. Some grains are traversed by needle-like lines, suggestive of rutile threads in quartz, which occasionally terminate abruptly against the inner surface of the transparent crystalline envelope. In some grains these threads form a parallel system, and in others they are set at all angles with one another. Very rarely they are curved or bent. In one grain, only ·02 in. × ·015 in., nearly fifty such threads occur. I have found this rutile-like structure also in the samples of the Potsdam sand from various horizons; in sand from the Pictured rocks of McGregor, Iowa, and in the St. Peter's sand.

Enclosures of another type are transparent spaces irregular in shape; some of these of the form of six-sided prisms, and others appearing to be cylindrical. One of the latter, occurring in a grain measuring ·016 in. × ·008 in., was ·0045 in. × ·0003 in. In another grain a tubular or prism-shaped cavity occurred measuring ·003 in. × ·001 in., with an *enclosed brown* spot ·001 in. long. A grain measuring ·013 in. × ·012 in. contained eleven of these transparent cavities.

Other enclosures are colored brown, yellowish, reddish, neutral, or nearly black. Some are evidently cavities with colored contents, a few with solid contents. One of the larger measured ·0045 in. × ·0035 in. Some are of irregular contour, but the most give hints of regular sides and forms. From one brown enclosure, ·0045 in. × ·0033 in., there extended a tube, at right angles, ·003 in. long × ·001 in. broad. In one grain, ·024 in. × .020 in., there was one brown cavity, ·007 in. × ·006 in., with upper and lower sides parallel planes; a second similar cavity, ·003 in. × ·002 in., in some positions showing a six-sided shape; a third cavity, drab colored, ·002 in. × ·001 in., and five minor ones, are plainly hexagonal. Such enclosures appear to be common to all horizons of Potsdam, and are found to some extent in St. Peter's.

In two instances I have found inclusions that were apparently minute grains of worn quartz. One was furnished by a nearly oval grain of sand, measuring ·03 in. × ·025 in., whose crystal envelope was very thin. Embedded in this grain, at a depth of ·005 in. from its upper surface, and nearly as much above the under, lay a grain of worn quartz of rounded outline. It measured ·0045 in. × ·0035 in. and was traversed by four paralell bands of cloudiness. The second instance occurred in a grain nearly oval, ·017 in. × ·014 in. across. The enclosed grain measured ·0035 × ·003 in. When viewed by reflected light it was very distinct in outline; and translucent, but in a less degree than the grain in which it was embedded.

The quarried rock, that is composed of this crystal-sand, gleams brilliantly in the sunlight. It may be worthy of record that the same sparkle of minute crystals appears also in the smooth surface of some of the fossil tracks, and in the ripple-marks, many of which are preserved with admirable distinctness.

The grain of sand figured above is one of special symmetry and completeness of finish, which shows well the relation of the crystal envelope to the imprisoned nucleus with its inclusions.

ART. VI.—*On the Origin of Jointed Structure;* by G. K. GILBERT.

IN the March number of this Journal, President LeConte proposes to explain the jointed structure of the Quaternary clays of the Great Salt Lake Desert by referring it to the same category with certain shrinkage cracks observed in recent Californian alluvial deposits. The cracks he describes form by their intersection "more or less rude approximations to quadrangular or hexagonal prismatic blocks,"—and these words seem to imply the irregular arrangement characteristic of sun cracks. The joints dividing the clays of the Desert have, on the contrary, a regular arrangement. In describing them in the January number of the Journal, I spoke of a drainage system to which they give rise, and said that the blocks marked out by that system are "rudely rectangular," but the adjective *rude* could not with propriety be applied to the blocks cut out by the joints, for these are well-defined parallelograms. The joints are definitely divided into two systems, one nearly at right angles to the other, and within each system they are parallel. For this reason I am led to regard the proposed explanation as insufficient.

When a moist clay stratum shrinks by drying, its fracture is resisted, first, by its internal cohesion, and second, by its adhesion to that on which it rests. The average size of the blocks into which it divides is determined by these two conditions—the cohesion tending to make them large, the adhesion to make them small. The forms of the blocks are determined primarily by the fact that the contraction is equal in all directions, and we may conceive that each block tends to be circular about its center of adhesion—becoming actually polygonal, with as many sides as there are contiguous blocks. The arrangement of the centers of adhesion follows no law, but is conditioned in part by slight inequalities of adhesion or cohesion, and is irregular. There is always some inequality in the size of the blocks and the number of their sides ranges ordinarily from 4 to 7. It is a general characteristic of the cracks thus formed that they meet but do not cross each other. If four come together in such way as to include equal angles it is purely a matter of accident. Ordinarily only three meet in a point and neither of the three is, properly speaking, the continuation of one of the others.

The features characteristic of sun cracks in clay are repeated wherever a superficial layer of any material shrinks so rapidly as to crack. They are illustrated by a great variety of cooling and drying processes in the arts, and conspicuously by the

cooling of lava beds. The system of cracks formed on the surface of a congealing lava stream are carried downward as solidification and contraction progress, and cause the rock to be divided into a system of polygonal, prismatic blocks.

Cracks of this type are included by some writers under the head of joints, but it will be convenient here to call them distinctively *shrinkage cracks* and follow Professor Dana in giving to the word *joints* a more restricted meaning. The joints which occur so generally in indurated rocks are characterized primarily by parallelism. By means of parallelism they are grouped in systems, and most rock-bodies are traversed by two or more of these systems. Their tracings at the surface constitute a lattice of straight lines or of lines nearly straight. The lines of two systems cross each other without interference. From each point of intersection lines go in four directions, and the alternate lines are prolongations of each other. Exceptional points can be found in which three lines meet, but the meeting always makes a letter T and never a letter Y—that is to say, two of the three meeting lines always agree in direction so as to constitute a continuous line, against which the third terminates. Usually the hammer will reveal an inchoate joint in the prolongation of the third line. In each of these respects joints differ from shrinkage cracks.

Joints of the same system are parallel; shrinkage cracks are not parallel. Joints of different systems cross each other; shrinkage cracks do not cross each other. In jointed structure the joint is the leading feature, the block is incidental, and the wide-spread evidence of system everywhere observed shows that the causative force either is diffused or is extraneous. In shrinkage-crack structure the causative force is localized in the shrinking block, and the crack is incidental.

Yet other points of difference could be enumerated, but enough have been adduced to show that the two series of phenomena are not closely parallel. Perhaps the shrinkage hypothesis for joints should not be set aside as absolutely untenable, but it certainly cannot be adopted until division planes demonstrably due to shrinkage are in some instance shown to have the peculiar characters of joints.

If we turn, now, to the relation between jointed structure and slaty cleavage, we find, to say the least, a close analogy. They agree in the parallelism of division planes. Just as one system of joints intersects another, so a system of joints is found to intersect a system of cleavage planes; and it is probable, though perhaps not certainly known, that two or more systems of slaty cleavage may exist in the same rock mass. The most striking difference between the two structures may possibly be one of degree merely:—in the case of joints the

parting planes are separated by wide interspaces, while in the case of slaty cleavage the interspaces are small. Another difference is exhibited by the internal structures of the blocks separated by the division planes. In slaty structure the blocks are themselves cleavable in the direction parallel to the planes of division, while in typical jointed structure the blocks are not thus cleavable. These two differences are perfectly evident when typical samples are considered, but it may be doubted if they are universal and diagnostic. Many examples are difficult to class with one type or the other, and there appears to be a gradation of character alike in regard to the thickness of the parted blocks and in regard to their cleavability. It is practically impossible to draw a hard and fast line between the two structures, and the geologists who regard jointed structure as identical with slaty cleavage certainly have much to say in support of their opinion.

When however we come to the question of cause, serious doubts arise. We have a well-sustained theory that slaty cleavage is due to compression, the direction of the compressing force being normal to the planes of cleavage. If this theory is true, and if joints are essentially identical with cleavage planes, then joints too are caused by pressure and compression. Should we grant this we must accept joints in every instance as evidence of compression, and we must conclude that all or nearly all level-lying strata have been subjected to coercive pressure from one or more directions. Two systems of joints must indicate pressure from two directions at two different times, for coincident pressures could only induce jointing planes normal to the direction of their mechanical resultant. The occurrence in the same rock-mass of a number of systems of joints, theoretically indicates the successive, and not the coincident, existence of the same number of mechanical stresses. The application of this rule to the Quaternary strata of the Salt Lake Desert imposes a severe strain upon the imagination, for it requires us to believe that a broad sheet of freshly-formed sediments—so fresh that the shore-trace of the formative lake has scarcely been impaired by the weather—has been compressed by forces acting first in one direction and afterward in a direction nearly at right angles. There are, indeed, evidences of Post-Quaternary orographic movements in the region, but those movements were small and vertical, and the type of structure exhibited by all the surrounding mountains is one implying vertical displacement and no lateral contraction.

If the theory of lateral compression were valid, and if each epoch of compression left its record in a system of joints, it would be reasonable to expect that the older strata would be

found to contain a greater number of joint systems than the newer, and that, *cæteris paribus*, there would be found a more or less gradual increase in the complexity of joint division from new rocks to old. Such, however, is not the case. Restricting our attention to those rocks which lie nearly level, we find that Paleozoic rocks rarely exhibit more than three or four joint-systems and frequently only two, while the same remark applies to Secondary and Tertiary rocks, and while the Quaternary clays of the Salt Lake Basin have two systems. In the range of my own experience the rocks freest from joints are the massive, cross-laminated, Triassic and Jurassic sandstones of the Colorado Plateaus, and these strata afford the only localities in which I have ever observed a *single* joint system. Indeed, the record of single systems of joints is so rare that I am disposed to question my own observation and suspect that the minimum number of coincident joint systems is two. However this may be, it is certainly an objection to the compression theory that, while the number of joint-systems in level-lying formations of all ages is frequently no more than two, it is rarely or never one.

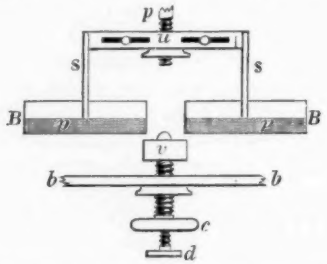
Now, unless we include the suggestion that joints have a magnetic cause, or the absolutely baseless hypothesis that they are due to shearing force, there seem to be only the two hypotheses above discussed to account for them. The most competent writers who have treated of them have classed them either with shrinkage cracks or with slaty cleavage, ascribing them on one theory to mechanical pulling and on the other to mechanical pushing. If the considerations here adduced have weight, then neither hypothesis is satisfactory, and the problem is an open one. It is certainly hard to correlate the parallelopipedons into which the clays of the Salt Lake Desert are divided with the polygonal prisms normally arising from shrinkage; and it is equally hard to admit that the clays have been subjected since their deposition to coercive pressure from two independent directions.

In my judgment it is proper to conclude, first, that joints are not due to shrinkage, and second, that the theory which regards them as identical with slaty cleavage and ascribes both to compression is untenable. If pressure and compression suffice for the explanation of slaty cleavage, then jointed structure is something distinct from cleavage and needs an independent explanation. If joints and cleavage are merely diverse examples of the same general structure, then the theory of slaty cleavage which has been so widely received fails to comprehend all the facts and needs to be revised.

Art. VII.—*Break-circuit arrangement for transmitting clock-beats;* by Francis E. Nipher.

[Read before the St. Louis Academy of Science, March 20th, 1882.]

A simple device for the transmission of clock-beats upon telegraph lines has been found so satisfactory in its action, that a description is here given for the benefit of any to whom it may be of service. The break-piece, which is represented in the cut, is best attached to the lower end, *p*, of the pendulum. It consists of a small brass bar which is screwed to the end of the pendulum rod, and set with a "jam nut" below. Two U-shaped strips of brass (*u*) are slipped around the vertical sides of the bar, to which they are clamped by bolts. The U strips are slotted to admit of lateral adjustment, as shown. Stiff strips



of brass (*s*) are soldered to the bottoms of the U pieces, and carry the two blades B which terminate below in platinum sheets *p*. It is evident that the adjustment of the slotted U pieces enables one to adjust the width of the gap between the blades B. For telegraphic transmission, where the signals are repeated, with a pendulum vibrating so that the amplitude chord is 2' inches, the interval between the blades should be about $\frac{7}{16}$ inch, while for chronographic work it should be somewhat smaller.

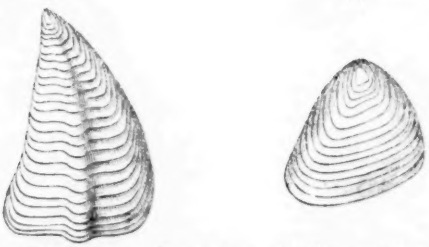
The mercury is, as is usual, contained in the hollow screw *c*, which is carried by the bed plate *b*. The screw *c* is tipped with a cylinder of wood or vulcanized fiber, and the mercury cavity terminates at the top in a long, narrow slot, at right angles to the plane of vibration.

This break is now in daily use by Professor Pritchett at the Observatory of Washington University, and the clock-beats are sent over something like ten thousand miles of wire. Arrangements now pending will increase the number of miles of wire to 28 or 30 thousand.

ART. VIII.—*Cirriped Crustacean from the Devonian;* by JOHN M. CLARKE.

THE genus *Plumulites* was erected by Barrande to cover certain fossils regarded by him as the capitulum plates of sessile Cirripeds and the name has been so interpreted as to cover the genus *Turrilepis*, proposed by Woodward (Quart. Jour. Geol. Soc. 1865) for a form which he regarded as bearing a scaly peduncle, the latter name having priority in time but not sufficiently carefully defined to entitle it to stand. Barrande, in regarding his specimens as all capitulum plates and not the scales of the peduncle, has based his conclusions upon the external markings of the plates rather than upon any such variation in shape and size as we should expect to find in the capitulum plates of a Lepadoid, and though his conclusions are probably correct, they are hardly fair deductions from his premises. It is interesting to notice that the species here to be mentioned and which closely resembles Barrande's species, *Plumulites fraternus*, shows some variation in the form of the plates, increasing thus the probability that they all belong to the capitulum, fig. 1 showing the more common elongate-triangular outline, being perhaps a *scutum*, and fig. 2 possibly one of the *latera*. In one example, four plates were found together, two having the outline of fig. 1, and two of fig. 2, the valves, thus of the capitulum having been detached but not scattered.

1. 2.



This species, *Plumulites Devonicus*, is from the base of the Hamilton shales at various localities in the towns of Canandaigua and Hopewell, Ontario Co., N. Y., and is interesting in being the first representative of fossil barnacles from the Devonian, Barrande's species of *Plumulites* and *Anatifopsis*, as well as the *Turrilepis* of Woodward being from the Upper and Lower Silurian and *Plumulites Jamesi* (Hall & Whitf., Pal. Ohio, vol. ii), from the Hudson River group.

Plumulites Devonicus.—Scutum (?). Length 4^{mm}, width at base $1\frac{1}{2}^{mm}$. Outline elongate sub-triangular or feather-like.

A curving median elevation runs from apex to base, growing more marked with each younger accretion to the valve. Lines of growth strongly marked. Nucleus apical. *Latus* (?). Length $2\frac{1}{2}^{mm}$, width 2^{mm}, round-triangular. Lines of growth strong; no median ridge; nucleus sub-apical.

May 4, 1882.

Since this note was put in type I have received from Mr. R. P. Whitfield a copy of a paper by him ("Descriptions of new species of Fossils from Ohio"), read before the New York Academy of Sciences and bearing the date of March, 1882. In this paper the identification of this genus *Plumulites* is announced, in the Huron (Genesee and Portage) shales, and a new species *Pl. Newberryi* described. Mr. Whitfield has, however, stated to the author his reason for feeling some doubt as to the advisability of referring his forms to this genus as they present considerable variation from the typical forms, though there can be no doubt of their Cirriped characters. *Pl. Devonicus*, however, so closely agrees with the type of the genus that, as suggested, it resembles almost to specific identity one of Barrande's species from Etage E. *Pl. fraternus*. *Pl. Newberryi* and *Pl. Devonicus* have no specific characters in common. J. M. C.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Absorption-Spectrum of Ozone.*—Chappuis has studied with care the absorption-spectrum of ozone. He finds it exceedingly characteristic, so much so that it serves for the detection of this substance better than any other of its physical or chemical properties. By its means he has investigated the decomposition of ozone by heat, the formation of ozone when carbon dioxide is subjected to the electric discharge, the production of pernitric oxide when oxygen and nitrogen are electrised, and other similar phenomena. The spectroscope used had two prisms, only one of which might be employed if desired. The ozonized oxygen was contained in a tube 4·5 meters long, and was prepared under atmospheric pressure and at 15° C. Eleven bands were observed in the spectrum, their wave-lengths being as follows: (1) 628·5, (2) 609·5–593·5, (3) 577·0–560·0, (4) 547·0–544·5, (5) 535·0–527·0, (6) 508·5–502·0, (7) 492·5–491·0, (8) 484·5–479·0, (9) 470·0–468·5, (10) 464·5–460·0, (11) 444·0. The first band was observed only twice and this where the ozone had been prepared with great care and was examined in a long tube. The second band is the most easily visible of all. It contains a darker portion near its center, from 603·5 to 597·0. The third band appears much darker in the region near D, the maximum being at 573·5. The other bands are alike in intensity and are nebulous on their edges. Photographs show absorption of the more refrangible rays but no new bands. By no method tried

could any of the bands be resolved into lines. As the thickness and the density of the gaseous layer increase, the bands increase in width and intensity and new ones make their appearance; a fact observed with nitrogen tetroxide by Brewster. The first bands which appear in the spectrum of ozone are 2 and 3. Then come 5, 6 and 8, and finally 10 and 11. Only in rare cases are 4, 7 and 9 seen, and 1 is extremely rare. Lowering of the temperature also deepens the color of the gas and increases the number and intensity of the bands. The blue liquid, obtained when a mixture of ozone and carbon dioxide is compressed, gives an absorption-spectrum essentially similar, showing both the absorption bands near the solar line D.—*C. R.*, xciv, 858, March, 1882.

G. F. B.

2. *On the Liquefaction of Ozone.*—When a highly condensed mixture of oxygen and ozone is suddenly expanded a dense mist appears; and from the character of this mist and the circumstances of its production, HAUTEFEUILLE and CHAPPUIS concluded that ozone was but a little less easily liquefiable than carbon dioxide. Upon mixing carbon dioxide and ozone together and compressing, they obtained a blue liquid. These authors have now succeeded in obtaining pure liquid ozone. By means of a Cailletet's apparatus a mixture of oxygen and ozone was compressed to 125 atmospheres. The glass tube containing the gas was recurved at its extremity so as to be immersed in liquid ethylene, by which its temperature was lowered probably to $-100°$ C. If the oxygen contains 10 per cent of ozone the ascending portion of the tube is colorless while the recurved and cooler portion shows a blue color. On sudden expansion, the entire tube becomes colorless and there appears at its capillary extremity a drop of dark indigo-blue liquid ozone. Once liquefied, it volatilized with extreme slowness. It remained for thirty minutes under a pressure of 75 atmospheres and its evaporation was not very rapid even when the pressure in the tube reached that of the atmosphere without.—*C. R.*, xciv, 1249, May, 1882.

G. F. B.

3. *On Nitrogen Sulphide.*—BERTHELOT and VIEILLE have examined nitrogen sulphide with a view to determine the heat of its formation. It is a beautiful, well-defined crystallized body having the formula N_2S_2 corresponding to the dioxide N_2O_2. It is produced by the action of ammonia gas on sulphurous chloride according to the reaction: $(NH_3)_8 + (S_2Cl_2)_3 = (NH_4Cl)_6 + N_2S_2 + (S_2)_2$. It is permanent in the air, detonates with violence under the hammer, and deflagrates at 207°. Its density at 15° is 2·22. The heat of detonation is: N_2S_2 solid $= N_2 + S_2$ solid, at constant volume $+64·4$ calories. The heat of formation is therefore negative: $N_2 + S_2 = N_2S_2$ solid $- 64·4$ calories. This body is therefore formed with absorption of heat like all the other binary compounds of nitrogen except ammonia. Hence it cannot be produced except by indirect methods, under the condition that the energy absorbed in the union of the nitrogen and the sulphur

be furnished by some auxiliary reaction. These constituents should therefore be in the nascent state, as it used to be called; they should come from preëxisting combinations the reciprocal actions of which, giving rise to new compounds, evolve more heat in their formation than the nitrogen sulphide absorbs. Thus in the above reaction the formation of hydrogen chloride and then ammonium chloride furnishes the energy absorbed in the formation of the nitrogen sulphide. The pressures developed in a closed space by the explosion of nitrogen sulphide are very near those obtained with fulminate for the same density of charge.—*Bull. Soc. Ch.*, II, xxxvii, 388, May, 1882. G. F. B.

4. *On Pernitric oxide.*—When especial precautions are not taken to avoid the presence of nitrogen in the oxygen submitted to the silent electric discharge, there is produced at the same time with the ozone, a compound of oxygen and nitrogen more highly oxygenated than nitrogen pentoxide, which gives a characteristic absorption spectrum, and to which Hautefeuille and Chappuis have given the name pernitric oxide. CHAPPUIS has examined the spectrum of this new oxide and finds it to consist of eight absorption bands. Since ozone is also present always, its bands are superposed upon the pernitric spectrum. But the intensity of the bands in the latter is much greater and they are more sharply defined. Traces even of the oxide show two lines between A and D in a region containing no ozone bands. Moreover, the oxide spectrum shows fine black lines in addition. The following bands were observed, the tube being two meters long: (1) 668·0–665·0, (2) 639·0, (3) 632·0–628·0, (4) 628·0–625·0, (5) 617·0, (6) 606·0, (7) 598·0, (8) 588·5–590·0. The lines 1 and 4 are the sharpest and the most intense; they are therefore the most characteristic and may be seen in a tube a decimeter long. Line 3 is gray and hardly separable from 4. It may be seen in a tube a meter long. Bands 6 and 7 are superposed on the second band of ozone. Their edges are nebulous and the above figures refer to their middle portion. They appear at the same time as band 8, which is superposed on D. These bands require a tube 1·5 meters long. Lines 2 and 5 are very fine and are seen when the length of the column is at least 2 meters.

In a second paper HAUTEFEUILLE and CHAPPUIS give the conditions of the formation of pernitric oxide. Like ozone the action of the electric discharge is limited, the maximum production corresponding to any given temperature being fixed by the diminution of volume which the gaseous mixture undergoes. Moreover there is a retrograde effect here as with ozone. As soon as the pernitric oxide has reached the maximum tension corresponding to the temperature, further discharges decompose it suddenly into nitrogen tetroxide and oxygen, shown by a sudden diminution of pressure and an intense red color. The heat thus set free destroys at the same time the ozone formed. If the nitrogen tetroxide be present in certain proportions, neither ozone nor pernitric oxide is reproduced by the discharge, if the tension be

considerable. At very feeble tensions, however, this re-formation takes place. Experiments made for the purpose showed that the maximum yield of pernitric oxide was, at 15° and 600mm., about 30 per cent, and that, independently of the proportions of the gaseous mixture. Lowering the temperature from 25° to 5° increased the product by one-quarter. In preparing pernitric oxide then, it is necessary to watch the progress of the conversion carefully so as to obtain the largest quantity and avoid retrogradation. This is best done by means of the spectroscope. In the author's apparatus the characteristic lines of pernitric acid appear at the end of about an hour.

In a third paper these authors give the results of their determination of the molecular weight and formula of pernitric oxide. On exposing the electrised mixture to a cold of −23°, crystals were obtained, but they were very volatile and in too small quantity for examination. The gaseous mixture was then exposed to concentrated sulphuric acid. Knowing its initial and the final composition, that of the absorbed portion was calculated. The following mixtures were electrised from an hour to an hour and a quarter at a temperature of 4° to 16°. Nitrogen 2 vols., oxygen 5·22, 5·56, 5·94, 6·18, 6·70, 7·63, 7·46, 9·51. The gas absorbed contained to 2 vols. nitrogen, 6·3, 6·2, 6·0, 6·5, 6·6, 6·2, 6·6 vols. oxygen. The latter ratio remains sensibly constant though the former varies widely. The mean ratio of nitrogen and oxygen absorbed by the sulphuric acid is 2 : 6·3. A second mode of fixing the composition of the pernitric oxide was based on the contraction which accompanied its formation. For this purpose the numerical value of the contraction, at the time when the electric discharges have given the maximum tension for the ozone and for the oxide produced at the temperature of the experiment, is noted and the volume of the nitrogen combined is determined. The sudden rupture of the equilibrium produced when the limiting tension is reached enables this volume to be fixed, since after this retrogradation the nitrogen of the pernitric oxide forms the tetroxide which is easily determined in a gaseous mixture when it contains no ozone. Both these indirect methods agree in assigning to pernitric oxide the formula N_2O_6. Further researches upon it are in progress.—*C. R.*, xciv, 946, 1111, 1306, April, May, 1882. G. F. B.

5. *On the Crystallization of Anhydrous Glucose from an Aqueous Solution.*—Anhydrous glucose has hitherto been obtained only from alcoholic solutions, methyl alcohol being the more recently used. Behr has found that anhydrous glucose may be made to crystallize from aqueous solutions. The hydrated product may be made to crystallize from its aqueous solution, as is well known, by the simple device of dropping in a few fragments of the solid. It occurred to Behr to drop into this aqueous solution a fragment of the anhydrous glucose. The next morning he was surprised to observe that the mass had crystallized, but with an appearance quite different from that ordinarily seen. By

centrifugal action the syrup was separated and after washing with methyl alcohol, the crystals had the fusing point, crystalline form, etc., of anhydrous glucose. The best result is obtained with a solution containing 12 to 15 per cent of water, though the result takes place within wide limits. The author has observed, further, that under certain conditions of concentration and temperature, the anhydrous product is the normal product of crystallization. Solutions of a purity of 97 to 98 solidify over night to a hard mass which, after the separation of the syrup, resembles loaf sugar. The importance of this observation to the industry of glucose cannot fail to be very great. The facility with which the result can be produced, the excellent appearance of the product, and the large use it will have in replacing loaf sugar made from the cane and the beet, all ensure its rapid introduction. The author estimates its sweetening power as compared with cane sugar as 1 : $1\frac{2}{3}$.—*Ber. Berl. Chem. Ges.*, xv, 1104, May, 1882. G. F. B.

6. *On the Transformation of Carbonyl Sulphide into Urea.*—Berthelot pointed out some time ago the fact that carbonyl sulphide and ammonia gas form, by their combination, oxysulphocarbamate of ammonium, transformable into urea by the simple elimination of hydrogen sulphide:

$$COS(NH_3)_2 = H_2S + CH_4N_2O.$$

In presence of metallic oxides this reaction is very sharp. He now finds that by simple evaporation of the aqueous solution of this salt, at a moderately high temperature, there is obtained a crystalline mass formed principally of urea but mixed with a notable quantity of sulph-urea, together with a little ammonium sulphocyanate, formed thus:

$$COS(NH_3)_2 = H_2O + CH_4N_2S.$$

This formation of both bodies is due either to the existence of two isomeric oxysulphocarbamates, or to two simultaneous reactions resulting from the multiplicity of the points of attack of a single one.—*C. R.*, xciv, 1069, April, 1882. G. F. B.

7. *Note on the Littrow form of Spectroscope;* by Professor C. F. Brackett, Princeton, N. J. (Communicated.)—In the employment of the Littrow form of spectroscope, in which a single tube serves for both collimator and telescope, great difficulty has been found in observing, on account of the light which is thrown back, by reflection, from the surfaces of the lens. As this form of spectroscope recommends itself from considerations of economy as well as those of convenience, it was decided to attempt the construction of one which should give great dispersion, on account of the very long focus of the lens employed. After consultation with Professor Young, whose well-earned distinction in spectroscopic studies is everywhere acknowledged, an order was given to Alvan Clark & Sons for the construction of a lens, with the following specifications: the lens to be of about eight feet focal length; the surface of the flint member of the combination looking towards the slit to have a radius of curvature equal to the focal length of

the combination,—a condition which evidently prevents the light reflected from this surface coming to the eye, since it can only pass back through the slit; the second surface of the flint to have the same radius as the contiguous surface of the crown, in order that the two may be joined with balsam, thus avoiding, as much as possible, reflection at these surfaces; the remaining surface to be determined by the conditions of focal length and the avoidance of spherical and chromatic aberrations.

These conditions having been fulfilled by the makers, notwithstanding the most careful blackening of the tube and the use of diaphragms, the amount of light coming back to the eye from the lens was found to be almost fatal to the usefulness of the instrument. But as all the surfaces of the lens, except that nearest to the slit, are of necessity curves of short radius, the light which can reach the eye must evidently come from a very small portion of them. It was only necessary, then, to cover this portion with a small blackened screen in order to escape all annoyance from this cause. The loss of light which the small screen cuts off from falling on the grating is very trifling,—not to be compared, in fact, with the inconvenience of the reflection which occurs without it.

The performance of the instrument as it now stands is quite equal to that which would be secured by one having the usual construction, with telescope and collimator mounted separately.

With a Rutherfurd grating of 17,000 lines to the inch, it can easily show many of the Fraunhofer lines, which the maps of Kirchhoff and Ångström lay down as single, to be composite.

Princeton, May 12, 1882.

8. *Relation between galvanic polarization and the surface tension of mercury.*—Many investigators have occupied themselves with the study of capillary phenomena presented by mercury, and the changes in these phenomena produced by electricity. Lippman has invented an electrometer whose action depends upon polarization produced by electrical currents at the surface of separation between mercury and dilute sulphuric acid. Lippman has also maintained that the magnitude of the capillary constant is modified by the difference of potential between the two liquids at the surfaces of which the phenomena are studied. A controversy upon this point has ensued between Lippman and Quincke, and Helmholtz suggested to Arthur König to complete an investigation which had already been begun in the Physical Laboratory, at Berlin. The experiments of Lippman were repeated and were extended to various acids and solutions of salts. In order to avoid the adhesion to glass surfaces, a form of apparatus was employed by means of which the mercury surface was bounded by a minimum surface of glass. The surface of the mercury was immersed in the solution employed and was observed by means of an opthalmometer. The ingenious arrangements by means of which the measurements of the change of shape of the mercury surface were made are given at length. Although the apparatus was placed upon a pier, the position of

the Berlin Physical Laboratory—in the midst of jars and tremors from the neighboring streets—interfered seriously with the work. It was found that with different fluids and with different values of potential, the surface tension had a certain maximum value—which subsided to a lower value—thus confirming the result of Quincke that a strong negative charge on the quicksilver resulted in a diminution of its surface tension. A careful study resulted in showing that the phenomena observed were due to electrical effects upon the mercury, produced by sudden rise in potential, and were not due to chemical change at the surfaces considered, thus confirming Helmholtz's views in regard to the influence of the layer of electricity (*doppelschicht*), upon the surface tension. The article of König contains some remarks of Helmholtz upon the electrical work done at the surface of separation between liquids, which results in diminishing the surface tension. —*Annalen der Physik und Chemie*, No. 5, 1882, pp. 1–38.

J. T.

9. *The change of color tones of spectrum colors and pigments with decreasing light.*—Certain observers, among whom is Dr. A. CHODIN, have maintained that there is a close analogy between the colors of pigments and the colors of the spectrum. The latter maintained that with diminution of light yellow, orange and green impress the eye more than blue and violet. On the other hand Purkinje states that pigments with diminishing light become colorless, and that blue continued to impress most. Dove noticed in a picture gallery that blue could be perceived with insufficient illumination better than red. E. Albert examines the subject anew and comes to the following conclusions: The analogy between the changes in spectral colors and in pigments does not exist. From the change of a homogeneous color no conclusion can be drawn concerning the change of the corresponding pigment, but the change of the latter is the result of the changes of the component homogeneous colors. The behavior of homogeneous colors under diminution of light is explained by the Young and Helmholtz theory, with the following addition: a reduction of the intensity of different colored lights betokens a diverse great lessening of sensitiveness in this wise, that for rays of smaller wave lengths, in whatever part of the spectrum they belong, it decreases more slowly than for waves of greater wave length.—*Annalen der Physik und Chemie*, No. 5, 1882, pp. 129–160. J. T.

10. *Specific resistance of Mercury.*—A new determination of the relation between the B. A. unit and the Siemens mercury unit has been made by Lord Rayleigh and Mrs. H. Sidgwick. According to Siemens' experiments—

1 mercury unit = 0·9536 B. A. units; and according to Matthiessen and Hockin,

1 mercury unit = 0·9619 B. A. units. Lord Rayleigh finds that

1 mercury unit = 0·95418 B. A. units.

Combining the result of the determination of the mercury unit with the value of the B. A. unit obtained by the same experimenter the following value results:

1 mercury unit = 0·94130×109 C. G. S.—*Proceedings Royal Society*, May 4. J. T.

11. *Eclipse of* 1882.—The following collective note of the results obtained was agreed upon by Lockyer, Tacchini and Thollon: "Photographs of the corona and of its complete spectrum were obtained by Schuster on Abney's plates, H and K being the most intense lines. A study of the end of the spectrum, of the corona and prominences was made by Tacchini. A comet which was very near the sun, and a very striking object, was photographed and observed with the naked eye. Bright lines were observed, before and after totality, of different heights, by Lockyer, and with intensities differing from the Fraunhofer lines by Lockyer and Trèpied. An absolute determination of the place of the coronal line at 1474 of Kirchhoff's scale was made by Thollon and Trèpied. The absence of dark lines on the corona spectrum was noted by Tacchini and Thollon with very different dispersions. Many bright lines in the violet were observed in the spectrum of the corona by Thollon, and were photographed by Schuster. Hydrogen and coronal lines studied in grating spectroscope by Paiseux, and in direct-vision prism by Thollon. Rings observed with grating by Lockyer, first, second and third orders. Continuous spectrum relatively fainter than in 1878, and stronger than in 1871. Intensity of absorption observed in group A, at the edge of the moon, by Trèpied and Thollon."—*Nature*, June 1, 1882. J. T.

12. *Diffraction gratings.*— Professor H. A. Rowland, in a preliminary notice contained in the Johns Hopkins University Circular, No. 16, gives some results of a new dividing engine. Owing to a new method of manufacture a very perfect screw was obtained, and by means of this, diffraction gratings with 43,000 lines to the inch were obtained. Surfaces $6\frac{1}{4}\times4\frac{1}{4}$ inches can be ruled by the machine. The screw is practically perfect and has been tested to $\frac{1}{100000}$ of an inch without showing any appreciable error. A flat grating 1 inch square with 43,000 lines to the inch divides the 1,474 line in the first spectrum. A flat grating $2\times3\frac{1}{4}$ inches, with 14,438 lines to the inch, shows the Z line, wave length 8,240, and as much below the A line as the B line is above the A line. Lines were also ruled on concave surfaces. These gratings allow the observer to dispense with a large part of the telescopic arrangements of a spectroscope. A concave grating $3\times5\frac{1}{2}$ inches, 17 feet radius of curvature, 28,876 lines to the inch, showed more in the first spectrum than was ever seen before. It divides 1,474 and E very widely and shows the stronger component of Ångström 5,275 double. J. T.

13. *On the methods for calibrating Thermometers;* by M. Thiesen, Berlin, Germany. (Communicated.)—I take this opportunity to call attention to an inaccuracy in two papers recently published

in this Journal by Mr. Russell (xxi, 373) and by Mr. Holman (xxiii, 278). In them reference is made to the papers of mine in Carl's Rep., xv, 285 (and 677) and in the Zeitschr. d. oesterr. Ges. f. Meteor., xiv, 426 as simply giving Neumann's method for calibrating thermometers. This method is given, in the papers referred to, quoted from Wild and Dorn, but there are also given amplifications and improvements of it by myself, which were indeed not difficult to find, but are now become a matter of importance.

In Holman's paper it is asserted that some of the advantages of Neumann's method are offset by the considerable error arising from taking readings with an end of the thread apparently just at the line of the scale. This method of taking readings, often recommended it is true, is by no means an essential part of Neumann's method nor was it adopted by myself; that will be seen from the examples given in the papers quoted. In the thermometers used in Germany it is not necessary to avoid particularly the coincidence of top and line, since they allow the top of the mercury to be seen *before* the lines of the scale.

I shall venture to add some remarks on the methods of calibrating thermometers, a matter too often disregarded, and about which there seems now to be some interest felt in this country. I think I am acquainted with all the important and many of the unimportant papers on this subject, but I have never found a method that is not superseded by one of the three methods I have described in the paper in Carl's Rep., viz:

1. The method of Lambert or Gay-Lussac, the oldest and simplest one, but not permitting very great accuracy. The method proposed by Holman does not differ materially from this. 2. The methods of Hällström requiring a greater number of observations and a more tedious calculation but which will answer in all ordinary cases. 3. The methods based on Neumann's principles requiring a great number of observations but giving the best results with little trouble.

By employing the method of least squares instead of No. 3 (a method which I may call Hansen's method, though Hansen proposed it for another matter) the labor of calculation is increased rather more than the accuracy; moreover, there is not always occasion for employing this method and it is not easy for everybody to be so acquainted with it as to be always ready to employ it.

To the famous method of Bessel and its modification by Oettingen, to-day only a historical value can be attributed.

II. Geology and Mineralogy.

1. *Abstract of a Report upon the Geology and Mining Industry of Leadville, Colorado;* by S. F. Emmons, Geologist-in-charge Rocky Mountain Division U. S. Geological Survey. 290 pp. 4to, with two colored plates. Washington, 1882. Extr. from Ann. Rep. Director Geol. Surv. of 1881.—The subject of the Report of which an abstract is here given is one of great interest, and the

character of it, as the abstract shows, is every way calculated to satisfy the reader. It is topographical, lithological, geological and economical in its range, and enters into full details under each of its subdivisions. It has many illustrations in the text and an Atlas of fourteen plates. The abstract, by the author, Mr. Emmons, gives a general review of the whole subject, and from it we make out the following brief sketch.

In the latitude of Leadville, 39° 15′, the Rocky Mountain chain includes (1) the Front or Colorado Range on the east; (2) the Mosquito or Park Range with peaks over 14,000 feet, next west—which slopes gently to the eastward and abruptly westward; and (3) farther west, the broader Sawatch Range equally high. Between the latter two ranges is the Arkansas Valley, 60 miles long and 16 wide; and on its eastern side, on the western flank of the Mosquito Range, is situated the city of Leadville, in longitude 106° 17′ W. and 10,150 feet above the sea "between Big Evan's and California Gulches at the base of Carbonate Hill." The first discovery of ore was made in 1860. In 1877 its population was less than 200, its opened mines *three*, and there were surface scratchings; in 1880 it was a city of 15,000 inhabitants, and its producing mines numbered over thirty.

The Paleozoic rocks of the Mosquito Range have a thickness of 4050 to 5600 feet and are more or less folded and faulted. They comprise (1) 200 feet of Cambrian or Primordial, chiefly quartzytes; (2) over these, 200 of Silurian (*white* or dolomitic limestone and quartzyte); and (3) 3700 to 4200 of Carboniferous, which last have 200 feet of limestone, called the *blue* limestone, at base and 1000 to 1500 at top (Upper Measures), with grits (Weber grits), sandstones and shales, partly calcareous, between. In the Kanab section on the Colorado, the Paleozoic has about the same thickness (85 feet of it referred to the Permian); but in the Wahsatch section cited, the thickness is 30,000 feet, 12,000 referred to the Cambrian, 3400 to the Silurian and Devonian, 15,000 to the Carboniferous and 650 to the Permian.

Besides these there are eruptive rocks—porphyries and diorytes—mostly Mesozoic in age. The common kind is the white porphyry, an evenly granular rock, consisting of quartz (70 per cent), feldspar (the latter occasionally in small rectangular crystals), black mica or biotite, and some muscovite. The rock is partly decomposed, and the muscovite "is the result of the decomposition of the feldspar." Other kinds of porphyry, more granite-like, consist of quartz, two feldspars and biotite, and in one variety hornblende is present. The dioryte is a porphyritic crystalline-granular variety. The white porphyry occurs to the south of an east-and-west line through Leadville, and the other kind north of this line. The main sheet of the former which lies upon the surface of the blue limestone forms, at the 4-mile Creek where is its principal vent, the larger portion of a hill 2000 feet high, and thence spreads southward reaching nearly to Buffalo Peaks. On Iron and Carbonate hills it has a possible thickness of over 1000 feet; but

along Evan's Gulch it will scarcely average 100, and even thins out entirely. Other sheets occur between lower strata, and there is a local sheet in the lower quartzyte or Cambrian. The intrusive masses of the other porphyries have a wider vertical distribution, "extending up to the Jurassic and possibly even to the Cretaceous." A single section exhibits "fifteen sheets, many several hundred feet thick, between the blue limestone and the top of the Carboniferous." The various sheets of porphyry form an integral part of the sedimentary series; they never reached the surface, but were spread out and cooled between deep-lying strata—laccolith-like, before the mountain-building epoch at the close of the Cretaceous, and therefore before the associated strata were folded or faulted. Archæan rocks make large parts of the Sawatch Range on the west, and of the Front Range on the east, and their areas must have been great islands in the Paleozoic seas. "The Paleozoic and Mesozoic beds are a littoral deposit around the Sawatch Archæan Island and were consequently formed in comparatively shallow waters."

Of later formations, the region contains only the Quaternary; what have existed of Mesozoic strata—probably not less than 10,000 feet—having been removed by erosion and abrasion.

Several faults occur, the more prominent of which have the strike of the rocks, or about N. 60° W. and the upthrow on the east side; and, of these, the Mosquito fault, west of the main crest of the Mosquito Range, amounts on the north to 5000 feet or more. Besides these there are many cross faults.

The ores occur underneath a porphyry sheet and chiefly in cavities penetrating the lowest member of the Carboniferous formation—the *Blue* limestone—but occasionally also underneath the same porphyry in the *White* or Silurian limestone, and the Cambrian quartzyte. The ore deposits penetrate into the limestone to varying depths from its plane of contact with the overlying igneous rock, sometimes following courses of natural joints or cleavage planes.

The ore is principally argentiferous galena and its secondary products lead carbonate, silver chloride, and, less abundantly, lead sulphate or anglesite, pyromorphite, minium, zinc blende and calamine. The gangue, or material mixed with or holding the ore, consists of hydrated iron oxides or manganese oxides, silica and clay, all secondary products, the clay coming from the decomposed porphyry. The cavities in the limestone were made by the eroding solutions which introduce the ores; the action commenced at the top of the limestone adjoining the sheet of porphyry, and from this plane worked downward into the limestone. The materials of the ores were taken from "circulating waters, which, in their passage through the various bodies of eruptive rocks, took up certain metals in solution, and, concentrating along bedding planes, by a metamorphic or pseudomorphic action of replacement, deposited these metals as sulphides along the contact or upper surface, and to greater or less depth below that surface, of beds gen-

erally of limestone or dolomite but sometimes also of siliceous rocks." Dikes intersecting the ore-bearing formation "seem to favor the concentration of rich ore-bodies or bonanzas in their vicinity;" but the planes of faults afford no deposits of importance, and evidently for the reason that "their origin is later than that of the original ore-deposits." Thus the intrusion of the igneous sheets preceded the production of the ore-deposits and of the cavities containing them; and the production of the ores antedated the era of great disturbance which closed the Lignitic period or the Cretaceous, and which has continued to be followed by feeble movements until the present time, even since the opening, according to some evidence, of the Leadville mines.

Mr. Emmons's abstract of his Report is, like all his geological writings, clear and precise in style, and of the best kind of science whether the subject is purely scientific or practical.

2. *Note on Alaska Tertiary Deposits;* by WM. H. DALL, U. S. Coast Survey. (Communicated in reply to a letter from J. D. Dana.)—Our present knowledge of the existence of Miocene deposits in northern Alaska depends on the identification by Dr. Newberry of certain leaf-bearing strata from Norton Sound and the Yukon River. All along the coast of Alaska there is a series of brown sandstones with marine fossils, which appear to be the same as the brown marine sandstones of the vicinity of San Francisco and Monterey. They are not of course *continuous*, but are found here and there in the same position relative to the conglomerates and shales under them which bear vegetable remains. The California sandstones are called Miocene, though they contain numerous shells chiefly of still-living mollusks. The shells in the northern strata are not characteristic, and belong to *Crepidula*, *Mytilus*, *Ostrea*, and some indeterminate Gasteropods, all extinct species as far as I have noticed, except in one deposit on St. Paul Island which may be of later origin. These brown sandstones are the top-rock in the Yukon valley at Nulato, where they cover a comparatively small area (say thirty miles along the river at most), the bluish underlying leaf-bearing shales and gritty slates covering a very much greater area, and extending to the coast at Cape Tolstoi on Norton Sound north of St. Michael's (which is later

East and West Section at the Shumagin Islands.

1. Tertiary; 2. Lavas; 3. Metamorphic; 4. Granite.

A. West peninsula of Unga Island.
B. Unga North Harbor.
C. East peninsula of Unga Sound.
D. Popoff Strait.
E. Popoff Island.
F. Strait between Unga and Nagai.
R. The submarine Ridge.
G. Island of Nagai.
H. Strait east of Nagai.
I. Twin Rocks.
J. Spectacle Island.
K. Big Koniushi Island.
L. Little Koniushi Island Strait.
M. Little Koniushi Island.
N. Twelve-fathom Strait.
O. Simeonoff Island.
P. Off shore fishing ground.
S.T. Sea-level.

basaltic rock, a formation appearing low down on the Yukon also). They are also the top-rock at the Shumagin Islands, where we have a very pretty section down to the Triassic or Jurassic syenites, which are the base rock of the country nearly every where.

(1) The marine brown sandstone with *Crepidula*, whale vertebræ, oysters, and fossil teredo-bored wood.

(2) Conglomerates brown and iron-stained with thin sandy layers bearing Sequoia and other vegetable remains.

(3) Bluish sandy slates and shales with *Platanus* leaves interstratified with conglomerates and layers of silicified wood and lignite beds. (This is the Miocene of Newberry and Heer.)

(4) Quartzites much metamorphosed but conformable.

(5) Syenites (or granites without mica).

Through all the later strata (1–4) irregular ejections of basaltic lavas.

The sketch of the Shumagin section, herewith sent, was made ten years ago. It is typical of the general sequence in many parts of the territory. At Bering Strait there are no fossiliferous rocks. The Diomedes are granitic domes, rounded and weathered into irregular shapes, but domes of "massive eruption" on Richthofen's hypothesis. The rocks of the Asiatic side are nearly all syenitic (at least so wherever I have landed). The American side is mostly the metamorphic quartzites and hard blue slates not fossil-bearing, with occasional patches (as in Kotzebue Sound) of lava and basalt of late origin. Northward we have the great ground-ice formation broken here and there by hills of Paleozoic age with characteristic fossils and coal of good quality.

On Aliaska Peninsula we have fossiliferous strata from the Jura up, with the same syenitic basis and superimposed Tertiary rocks. The Miocene plant and marine strata, as here considered, have not been noted northwest of the east coast of Norton Sound on the seacoast, nor much north of Nulato on the Yukon. Leaving them and going east on the river, we come upon quartzites and conglomerates, and strike the syenite at the junction of the Yukon and Tananah Rivers; farther eastward the region is probably Devonian, but covered by alluvial deposits near the river; the Devonian rocks actually come out near Fort Yukon, on the Porcupine River.

The general depression of the Alaska region indicated by the Tertiary beds probably could not have exceeded 1500 feet, and was perhaps less. But how to reconcile the general absence of marine tertiary strata over the region *adjacent to the strait* with a submergence there I do not quite clearly see. There was a depression farther east, of course, and farther south, but *at* and *near* the straits it seems more doubtful.

3. *Origin of Jointed Structure;* by J. H. KINAHAN. (From a letter to J. D. Dana, dated, Geological Survey of Ireland, April 15, 1882.)—Mr. G. K. Gilbert and Professor J. LeConte's articles on the "Origin of Jointed Structure in undisturbed Clay and Marl Deposits" are of considerable interest to me. For years I

have believed that many geologists give much less credit to "shrinkage fissures" than they are entitled to. This cause is advocated in my "Valleys and their relations to Fissures, Fractures and Faults," especially in chapter ii; also in different memoirs to accompany the maps of the geological survey of Ireland. In Connemara or West Galway many of the narrow deep gorges I believe to be due nearly solely to the drying and contraction of the rocks after they became dry land; while in different places in the county of Clare there are, under the basal Carboniferous conglomerate sandstone and shales, peculiar siliceous or calcareous rocks that send down dykes into the underlying Cambro-Silurian rocks; and these dykes and other intrusions, as stated in the memoirs, I believe to have filled "shrinkage fissures" in the older rocks. Similarly, in the counties Mayo and Galway, the basal bed of the Silurians (or Lower Old Red Sandstone) intrudes downward, filling fissures in the metamorphosed Cambro-Silurians. In the coals of the Coal-measures many of the "troubles" or "horses" were filled from above, and anciently were "shrinkage fissures;" while in other places it appears to me many dykes of "fault-rock" are the filling in from above of "shrinkage fissures."

4. *American Geological Society.*—The proposal to organize an American Geological Society was brought up at the last meeting of the American Association, and a committee was appointed to consider the advisability of it and report at the next meeting. This committee consists of N. H. Winchell of Minneapolis, Minnesota, John H. Proctor of Frankfort, Kentucky, H. S. Williams of Ithaca, N. Y., John Collett of Indianapolis, G. C. Swallow of Columbia, Missouri, Wm. J. Davis of Louisville, Ky., and S. A. Miller, of Cincinnati, Ohio. The chief objection to it, offered at the time of proposal, was that the American Association included as one of its essential parts a geological association, and offered all the advantages needed by geologists in case the society was to have only annual meetings and no permanent place of meeting; and the objection appears to be good. The division would weaken the American Association without any necessary compensating advantage. The establishment, however, of an American Geological Society at some central city, for monthly meetings, might promote greatly the progress of the science, if it should have men and money to sustain it. Money would be freely needed in order that all memoirs offered might be fully illustrated.

5. *Catalogue of the Fossil Foraminifera of the Collection of the British Museum* (Natural History); by Professor T. Rupert Jones, F.R.S., F.G.S., etc. 100 pp. 8vo. London, 1882.—This catalogue is of value to investigators and collectors outside of England. It is prepared by one who has published largely on the subject, and is recognized as high authority in the department; it is both stratigraphical and geographical in arrangement; and contains references to many of the works and articles treating of the species.

6. *Brief Notices of some recently described minerals.*—HIERATITE—Occurs at the fumaroles of the crater of Vulcano, one of the Lipari Islands. It forms a part of stalactitic concretions of a grayish color, generally of spongy texture, rarely compact and vitreous. These concretions consist of very small crystals of the new mineral, lamellæ of boracic acid, and are veined with selensulphur, arsenic sulphide, etc. An analysis of the octahedral crystals, separated from the aqueous solution, showed them to have the composition of a potassium fluo-silicate, $2KF+SiF_4$. The concretions also contain potassium alum, and cæsium and rubidium alum, with small quantities of thallium. The name is given from *Hiera*, the Greek name of Vulcano.—Cossa in *Trans. Acad. Linc.*, III, vi, 141.

GUNNISONITE—A massive substance of a deep purple color, intimately mixed with calcite. H. about 4. G.=2·85. An analysis, after the deduction of 12·75 p. c. of admixed calcite, yielded CaF_2 74·89, CaO 11·44, SiO_2 6·87, Al_2O_3 5·95, Na_2O 0·85=100. From the neighborhood (20 miles south) of Gunnison, Colorado. The describers, Clarke and Perry, suggest that it may be an alteration product of fluorite, or a mixture of that species with a silicate, though the mineral seemed to be homogeneous. The name is only given provisionally, but it is to be regretted that it was not withheld until the very serious doubt as to the homogeneity of the substance under examination was decided.—*Amer. Chem. Journ.*, iv, 140.

URANOTHALLITE.—Schrauf has given this name to a uranium carbonate from Joachimsthal, partially described by Vogl, and analyzed by Lindacker (see Dana, Syst. Min., 5th ed., p. 717). Schrauf makes the crystals, which form confused aggregates, orthorhombic with an axial ratio near that of aragonite. An analysis on 0·15 gr. gave him results agreeing with those of Lindacker, viz: CO_2 22·95, UO_3 36·29, CaO 16·42, H_2O 23·72=99·38, for which he calculates the formula $UC_2O_6+2CaCO_3+10$ aq. *Zeitsch. f. Kryst*, vi, 410. Schrauf has also studied the minerals occurring in the serpentine region near Budweis in Southern Bohemia. He describes in detail the method of association both of the original minerals and those produced by alteration. In the course of his development of the subject, he introduces a number of new names for intermediate varieties allied to serpentine; the names, however, seem rather unnecessary as the substances named are certainly not distinct species; they are KELYPHITE—a serpentinous substance coating altered crystals of pyrope; ENOPHITE—a chloritic variety of serpentine; hallite of Cooke is related; LERNILITE—in composition near the vermiculite of Lerni (Cooke), hence the name; SILICIOPHITE—the result of continued alteration, yielding from the serpentine (formed the chrysolite) a heterogeneous substance remarkable for its high percentage of silica; HYDROBIOTITE—a hydrated biotite from the granulite adjoining the serpentine (this name was previously used by Lewis in connection with his description of philadelphite); BERLAUITE—a chloritic substance

filling cavities between the granite and serpentine near others of the vermiculite group; SCHUCHARDTITE—the so-called chrysopraserde from Gläserndorf, Silesia. (Syst. Min., 5th ed., p. 510, H_2O =21·03, not 31·03). Schrauf uses the name PARACHLORITE for these substances whose constitution can be expressed by the general formula $m(Al_4Si_2O_{12})+n(R_2SiO_4)+p$ aq; also, PROTOCHLORITE for those corresponding to $m(Al_2SiO_5)+n(R_2SiO_4)+p$ aq.—*Zeitsch. f. Kryst.*, vi, 321.

MOLYBDOMENITE, COBALTOMENITE. — The remarkable copper selenite from Cacheuta, Argentine Republic, called chalcomenite by Descloizeaux and Damour, has been described in this Journal (xxii, 155). To this new group of minerals Bertrand has added two others from the same locality, a lead selenite and a cobalt selenite. The first, *molybdomenite* (μολυβδος *lead*, and μήνη moon), occurs in very thin white lamellæ, with a vitreous luster and nearly transparent; crystalline system orthorhombic, cleavage in two directions. Affords lead oxide and selenious oxide; some varieties have a greenish color and contain a little copper. The *cobaltomenite* is associated with the other mineral in the midst of the selenides of lead and cobalt. It occurs in very minute rose-red crystals resembling erythrite, but differing from it optically. Associated with these minerals is another which appeared to be pure selenium dioxide, entirely volatile.

7. *Statistics of the Production of the Precious Metals in the United States;* by CLARENCE KING. Tenth Census of the United States, Francis A. Walker, Superintendent. Department of the Interior. 94 pp. 4to.—This is a very carefully prepared report, covering all the divisions of the subject connected with the production of the precious metals in the different States and Territories. Mr. King in his "letter of transmittal" observes that this statistical statement is presented in advance of his report on the production of the precious metals, because of "its immediate interest to legislators, financiers and metallists."

8. *Supposed organic remains in meteorites.*—The fanciful conclusions of Dr. Hahn (vol. xxiii, p. 156), that meteorites of the chondrite class contain many distinct fossil remains, have found a supporter in Dr. D. F. Weinland, of Esslingen. In a brief pamphlet published recently, he describes and names some sixteen different genera and a large number of species; most of these he refers to the polycystines, sponges and foraminifera, with a few corals and crinoids. It is to be regretted that the extended study of the microscopic structure of meteorites, here recorded, should not have been directed by sounder judgment.

9. *Notes on the Mineralogy of Missouri*, by ALEXANDER V. LEONHARD.—Mr. Leonhard has given a brief descriptive catalogue of the mineral species of Missouri and a list of the important mineral localities. It would be well if the same work could be done with equal care for every State in the Union.—*Trans. St. Louis Acad. Sci.*, vol. iv, No. 3.

III. Botany and Zoology.

1. *Characeæ Americanæ Exsiccatæ, distributæ* a T. F. Allen, M.D.—Fasc. I was issued some time ago; fasc. II and III we have just now received. Thus far 30 species or varieties are represented by admirable specimens, carefully mounted, with printed tickets, giving needful details. The sets, as we understand, are not put on sale, but are presented by the author to those, among others, who will contribute for the continuation of the work about 100 specimens of any desired species or variety, properly prepared. Parallel with the issue of the *Exsiccatæ* we may expect further papers, like those recently issued, with creditable illustrations, in the Bulletin of the Torrey Club for April and the American Naturalist for May last. And at length we may have the "American Characeæ" illustrated in systematic order and with the completeness of fuller knowledge. A. G.

2. *Versuch einer Entwicklungsgeschichte der Pflanzenwelt insbesondere der Florengebiete seit der Tertiärperiode*, von Dr. Adolf Engler. Part I, 1879, Part II, 1882. Leipsic (Engelmann).—The first part of this History of the development of the Vegetable Kingdom since the Tertiary period, which is concerned with the flora of the northern hemisphere, fills 202 octavo pages; the second, which treats of the southern hemisphere and the tropical regions, fills 386 pages, including a very full index. There are two maps, one for the Tertiary period, one illustrating the present distributjon of plants. A very important work, which we can here only announce, but which we may hope before long to give the account of which it well deserves. A. G.

3. *The Genus Isoëtes in North America;* by Dr. George Engelmann.—We must announce this essay, though we have not room for an abstract of it. It is separately issued, in 33 pages, 8vo, from the fourth volume of the Transactions of the St. Louis Academy of Science, to which it was communicated in February last. The author, with customary thoroughness, gives the history of the genus as to this country, from the time of Pursh, who found what he took for *Isoëtes lacustris* in Oswego River, down to the present memoir, in which he fully characterizes fifteen species, the latest (*I. Howellii*) discovered in 1880, and discusses the morphology, biological characters, systematic arrangement, distribution, etc. Several of our botanists are naturally desirous of helping on the science by doing some special original work. Let them take this paper as a model. A. G.

4. *Flore de la Gironde;* par A. Clavaud. Paris, Masson; Bordeaux, Feret. 8vo.—We have received the first part of this new Flora of the Bordeaux district, containing the *Thalamifloræ*, in 222 pages, issued in 1882, and we perceive that it is a work of real character. It is wholly in French, gives full descriptions, also keys both to genera and species, and in both the more diagnostic characters are italicized after the manner of Koch and of

Gray's Manual. What adds to the value of the work is, first, that the descriptions are not only drawn from the plants themselves, but exclusively from the plants of the district; and, secondly, grades of relationship are very carefully exhibited. We have first the *species* in the Linnæan sense, and as we should regard them, although the author in his preface prefers to call them *stirpes*, regarding them rather as the stocks of species. The more strikingly differentiated portions of such a group, the sub-species of other authors, he designates as the *species*, and arranges them under the more generalized *stirps* in full-faced type. The less marked or subordinate forms, or varieties proper, have the names printed in italic type. The author refers to Braun as his sole predecessor in this mode of representation; but he might have mentioned Ball's Spicilegium of the Marocco flora. But both Ball and Braun keep to species, sub-species and variety, as botanists who deal with plants over wide regions may be expected to do.

There is an accompanying atlas of figures, after the manner of Cosson's Flora of the Environs of Paris. Eight plates of this atlas accompany the first installment of the Flora. They illustrate very neatly the sub-genus *Batrachium*, critical forms of *Fumaria*, *Viola*, *Polygala*, *Cerastium*, etc. A. G.

5. *Beitrag zur Kenntniss der Ustilagineen;* by M. Woronin. —This paper of 35 quarto pages forms the fifth portion of De-Bary and Woronin's Beitræge zur Morphologie und Physiologie der Pilze, and rapidly follows part four, which was recently reviewed in this Journal. The greater part of the article is devoted to the development of *Tuburcinia Trientalis* B. & Br., which is parasitic on *Trientalis europæa*. In the spring and early summer it forms whitish spots on the leaves and young stems, due to the conidia, which are pear-shaped bodies borne on stalks that project through the epidermis. The conidia were formerly described by Berkeley under the name of *Ascomyces Trientalis*. In the autumn the *Tuburcinia* forms black spots in the leaves, in which a microscopic examination shows an abundance of the aggregated spores characteristic of the genus. The author describes in detail the germination of the conidia, and the formation and germination of the aggregated spores. The latter arise from swollen portions of the hyphæ; but the process is soon obscured by a growth of lateral hyphæ which completely hide the spores in the later stages of formation. Each one of the aggregated spores can germinate singly and produce a promycelium, at whose tip is a whorl of sporidia which usually, but not always, connect with one another by a series of conjugating processes, as in *Tilletia*. But *Tuburcinia* differs from the last named genus in that the upper part of the promyceluim, which is separated from the basal part by a cell-wall, drops from its attachment together with the attached sporidia, and therefrom grow the latter secondary or even tertiary sporidia, and ultimately a mycelium is formed. Woronin then describes the development or more particularly the germination of several species referred by different writers to

Sorosporium, *Thecaphora*, *Entyloma* and *Melanotænium*. *Sorosporium Junci* Schr., he makes the type of a new genus *Tolyposporium*. In this connection is the only direct reference to American species, viz: *Sorosporium Astragali* Peck and *S. Desmodii* Peck are referred to *Thecophora* in consequence of the structure of their spores. The article ends with a synopsis of the genera of *Ustilagineæ*, and is illustrated by four partly colored plates, which, as is always the case in Woronin's articles, are beautifully executed. W. G. F.

6. *Salmon Disease.*—The existence of an epidemic disease in the Salmon of some Scottish and British rivers (a disease existing also in North America and Siberia), led to the appointment of Commissioners in 1879 to examine the facts. Prof. Huxley has a paper on the "Pathology of the epidemic known as the Salmon disease" in the Proceedings of the Royal Society for March 2, 1882, from which the following facts are taken. He observes that "the evidence taken by the Commissioners* leaves no room for doubt that the malady is to be assigned to the large and constantly increasing class of diseases which are caused by parasitic organisms. It is a contagious and infectious disease of the same order as ringworm in the human subject, muscardine among silkworms, or the potato disease among plants; and, like them, is the work of a minute fungus. In fact, the *Saprolegnia*, which is the cause of the salmon disease, is an organism in all respects very closely allied to the *Peronospora*, which is the cause of the potato disease.

It is a very curious circumstance, however, that while the *Peronosporæ* are always parasites—that is to say, depend altogether upon living plants for their support—the *Saprolegniæ* are essentially saprophytes; that is to say, they ordinarily derive their nourishment from dead animal and vegetable matters, and are only occasionally parasites upon living organisms. In this respect they resemble the *Bacteria*, if the results of recent researches, which tend to show that pathogenic bacteria are mere modifications of saprogenic forms, are to be accepted."

The disease covers the skin of the salmon, wherever it is attacked, with a "papyraceous slough-like substance," which is a *mycelium* or felt-like fungus; and the *zoospores* set free are the source of the contageousness of the disease. Prof. Huxley made experiments on the transplantation of the *Saprolegniæ* of the living Salmon to dead animals.

"The body of a recently killed common house-fly was gently rubbed two or three times over the surface of a patch of the diseased skin of a salmon and was then placed in a vessel of water, on the surface of which it floated in consequence of the large

* "Report on the Disease which has recently prevailed among the Salmon in the Tweed, Eden, and other Rivers in England and Scotland." By Messrs. Buckland, Walpole, and Young, 1880.

See also the three valuable communications to the "Proceedings of the Royal Society of Edinburgh," made by the late Mr. A. B. Stirling in 1878–79.

quantity of air which a fly's body contains. In the course of forty-eight hours, or thereabouts, innumerable white cottony filaments made their appearance, set close side by side, and radiated from the body of the fly in all directions. As these filaments had approximately the same length, the fly's body thus became inclosed in a thick white spheroidal shroud, having a diameter of as much as half an inch. As the filaments are specifically heavier than water, they gradually overcome the buoyancy of the air contained in the tracheæ of the fly, and the whole mass sinks to the bottom of the vessel. The filaments are very short when they are first discernible, and usually make their appearance where the integument of the fly is softest, as between the head and thorax, upon the proboscis, and between the rings of the abdomen. These filaments, in their size, their structure, and the manner in which they give rise to zoosporangia and zoospores, are precisely similar to the hyphæ of the salmon fungus; and the characters of the one, as of the other, prove that the fungus is a *Saprolegnia* and not an *Achlya*. Moreover, it is easy to obtain evidence that the body of the fly has become infected by spores swept off by its surface when it was rubbed over the diseased salmon skin. These spores have in fact germinated, and their hyphæ have perforated the cuticle of the fly, notwithstanding its comparative density, and have then ramified outwards and inwards, growing at the expense of the nourishment supplied by the tissues of the fly."

"Having infected dead flies with the salmon *Saprolegnia*, once from Conway and once from Tweed fish,* I was enabled to propagate it from these flies to other flies, and, in this manner, to set up a sort of garden of *Saprolegniæ*."

"Whether the zoospores are actively locomotive or not, they are quite free when they emerge from the zoosporangia; and, from their extreme minuteness, they must be readily carried away and diffused through the surrounding water. Hence, a salmon entering a stream inhabited by the *Saprolegnia* will be exposed to the chance of coming into contact with *Saprolegnia* spores; and the probability of infection, other things being alike, will be in proportion to the quantity of the growing *Saprolegnia*, and the vigor with which the process of spore-formation is carried on. At a very moderate estimate, a single fly may bear 1,000 fruiting hyphæ; and if each sporangium contains twenty zoospores, and runs through the whole course of its development in twelve hours, the result will be the production of 40,000 zoospores in a day, which is more than enough to furnish one zoospore to the cubic inch of twenty cubic feet of water. Even if we halve this rate of production, it is easy to see that the *Saprolegnia* on a single fly might furnish spores enough to render such a small shallow stream as salmon often ascend for spawning purposes, dangerous for several days. But a large fully diseased salmon may

* And since this paper was read once more from the North Esk fish. (March 8, 1882.)

have as much as two square feet of its skin thickly covered with *Saprolegnia*. If we allow only 1,000 fruiting hyphæ for every square inch, we shall have 288,000 for the whole surface, which, at the same rate as before, gives over 10,000,000 spores for a day's production, or enough to provide a spore to every cubic foot of a mass of water 100 feet wide and 5 feet deep and four miles long. Forty such diseased salmon might furnish one spore to the gallon for all the water of the Thames (380,000,000 gallons per diem) which flows over Teddington Weir. But two thousand diseased salmon have been taken out of a single comparatively insignificant river in the course of a season.

It will be understood that the above numerical estimate of the productivity of *Saprolegnia* has been adopted merely for the sake of illustration; that I do not intend to suggest that the zoospores are evenly distributed through the water into which they are discharged by the zoosporangia; and that allowance must be made for the very short life of those zoospores which do not speedily reach an appropriate nidus. Nevertheless, the conclusion remains arithmetically certain that every diseased salmon adds immensely to the chances of infection of those which are not diseased."

The author shows that the hyphæ penetrate the true skin, but obtained no evidence that they "break up into toruloid segments (as in the case of *Empusa muscæ*), and thus give rise to general septic poisoning or fungoid metastasis." The epidermis is destroyed, and its place is taken by a thick, felted mycelium, which entangles the minute particles of sand that are suspended in the water, and this no doubt constitutes a very irritating application to the sensitive surface of the true skin." Death results without any other organ being affected, and is "the consequence partly of the exhaustion of nervous energy by the incessant irritation of the felted mycelium with its charge of fine sand, and partly of the drain of nutriment directly and indirectly caused by the fungus."

The *Saprolegnia* has not been observed on decaying bodies in salt water; and there is only one case on record of any fungus occurring on a fish in salt water.

IV. Miscellaneous Scientific Intelligence.

1. *Bibliographie générale de l'Astronomie* ou Catalogue méthodique des ouvrages, des mémoires et des observations astronomiques publiés depuis l'origine de l'imprimerie jusqu'en 1880, par J. C. Houzeau et A. Lancaster. Tomé second: Mémoires et notices insérés dans les collections académiques et les revues; quatrième fascicule, columns 1548–2225. Brussels, April, 1882.—The part, now issued, forms the conclusion of the second volume of this most valuable work. It contains the following heads: history and study of astronomy; biographies of astronomers; spherical astronomy; theoretical astronomy; celestial mechanics; physical astronomy; monographs on the solar system. The vol-

ume concludes with an alphabetical index of the authors whose works are mentioned in this volume. It is the complete methodical catalogue of astronomical memoirs and is indispensable to astronomers. The first and third volumes of the *Bibliographie* will contain books and astronomical observations.

2. *Life in Hawaii, by the Rev. Titus Coan.* 340 pp. 12mo. New York: A. D. F. Randolph & Co.)—This autobiographic sketch of mission life and work, besides its deep interest on account of the great successes of the author's labors among the Hawaian people, has a value also to science from his various explorations of the Hawaian volcanos. Mr. Coan has been since 1840, as the readers of this Journal are aware, the chief source of information with respect to the eruptions. He has made at least "a hundred" visits to Kilauea, studying its phases, and has traced the courses of its eruptions and also of those of the summit crater, one of the latter from a height of 12,000 feet. His vivid descriptions, the last little over a year old, have given the world a large part of what has hitherto been known about the movements of the two craters. This volume will therefore always have a place among works of original observation on volcanic phenomena.

3. *Studies in Science and Religion;* by G. FREDERICK WRIGHT, author of the "Logic of Christian Evidences." 390 pp. 12mo. Andover, 1882 (W. F. Draper).—The author of these "Studies" understands well both sides of his subject—the arguments which come from recent developments in science, including their bearings on theories of evolution, and those which proceed from the subordination of the natural to the theistic. All classes of readers may derive profit from his able discussions with respect to evidence from nature and Darwinism on the one side and religion or Christianity on the other. One of the later chapters is an essay on prehistoric man, in which known facts are briefly reviewed, and the special facts from America; and those of the Trenton Gravel are given with more detail, the latter largely from Mr. Wright's personal investigations.

4. *Knight's New Mechanical Dictionary*, in four sections, large 8vo. Boston (Houghton, Mifflin & Co.) A description of tools, instruments, machines, processes, and engineering with indexical references to technical journals, by EDWARD H. KNIGHT, A.M., LL.D.—Knight's Mechanical Dictionary is a work well known and whose value is thoroughly appreciated. It gives in three volumes, aggregating 2,831 pages, a very complete digest of mechanical appliances in science and the arts. It was completed in 1876, and the publishers now announce that the remarkable progress which has been made during this time in the department of the mechanical arts and the application of science to industrial uses, has induced them to undertake the issue of a supplementary volume. This will continue the record from the date of the former work, and give in alphabetical order a discussion of each topic included under the general head, with a large number of illustrations. The volume will also contain a complete index to technical literature,

giving under each subject a list of all the articles which have appeared from 1876 to 1880 inclusive, in the pages of English and American technical journals. The work is to be published in four sections of 240 pp. each, to be ready every second month, commencing with June.

5. *Report of the Board of Regents of the Smithsonian Institution for* 1880.—The Report of the Secretary, Professor Baird, on the organization of the Institution and its work and progress, in its various departments, during the year 1880, is followed by a General Record of Scientific Progress for the year: in Astronomy by Professor E. S. Holden; in Geology and Mineralogy by G. W. Hawes; in Physics and Chemistry by Professor G. F. Barker; in Botany by W. G. Farlow; in Zoology by T. Gill; and in Anthropology by O. T. Mason. It also contains a paper on the Luray Cavern from an examination made under the auspices of the Institution in July, 1880; a discussion of Professor Snell's barometric observations by T. H. Loud; an investigation of illuminating materials by the late Secretary, Professor Henry (reprinted from the Report of the Light House Board for 1875); Synopsis of the scientific writings of William Herschel, by E. S. Holden and C. S. Hastings; and Reports of Astronomical observatories.

6. The *British Association* meets, August 23d, at Southampton, C. W. Siemens, Esq., President; the *French Association*, August 24th, at La Rochelle, M. Janssen, President; and the *Helvetian Association*, September 11th, at Linthal, in the Canton of Glaris, Dr. F. Kœnig, President.

OBITUARY.

William Barton Rogers, President of the National Academy of Sciences, and long one of the ablest of American men of science, died suddenly at Boston, May 30, while in the act of delivering an address before the Massachusetts Institute of Technology, of which he was the founder and the first president. The occasion was the graduation exercises of the Institute. Professor Rogers was announced for a short address, at the close of the exercises. His appearance was the signal for prolonged and enthusiastic applause which deeply moved him. He commenced speaking with deep emotion, when suddenly he fell lifeless to the floor without a struggle.

Professor Rogers was born in Philadelphia, in 1805, and was the second son of Dr. P. K. Rogers. His father was Professor of Physics and Chemistry at the college of William and Mary, in Virginia, from 1819 to 1829, when he was succeeded by his son William, who held the position until his removal to the University of Virginia, in 1835. He discharged there with distinguished ability the duties of the Chair of Physics, and also of instruction in mineralogy and geology until 1853, when he removed to Boston. The writer has a vivid memory of a lecture on the resultant of force which he heard Professor Rogers deliver at the University of Virginia in the autumn of 1835, when

the lecturer was in the prime of his manhood, at thirty years, and had already developed those charming qualities of method and discourse which always made it a pleasure to follow him, even on subjects of no more than ordinary interest.

In 1835 Professor Rogers organized a geological survey for the State of Virginia, but after several years of a struggling existence and the publication of some annual reports of progress, in 1842, the effort was abandoned for want of any adequate support from the State. The materials accumulated for a final report have never been published, but Professor Rogers united with his brother, Henry Darwin Rogers, geologist of Pennsylvania, in the authorship of a memorable memoir on the structure of the Appalachians in Pennsylvania and Virginia. This paper was jointly presented by the two brothers, at Boston, in the autumn of 1842, before the session of the American Association of Geologists and Naturalists. It excited the greatest interest among geologists and physicists on account of the novelty of its views, supported as they were by ample data and numerous sections, and the eloquence with which the whole subject was set forth. This was the first important contribution to dynamical and structural geology which, up to that time, had been brought forward in this country. With it appeared, also for the first time, the notation and nomenclature of the Appalachian system of rocks, now so familiar, through the Reports of the Geological Survey of Pennsylvania. An important paper on the "Connection of Thermal Springs in Virginia with Anticlinal Axes and Faults," by Professor William B. Rogers, was presented at the same meeting, and both papers were published in the Transactions of the Association for that year.

But probably the most important life work of Professor Rogers was that connected with the Massachusetts Institute of Technology at Boston, an institution which owes its existence, mainly, to his zeal and untiring industry, through which, in 1860, 1861, he secured for it the support of the State and of individual founders. The work was crowned with success, and in 1862 Professor Rogers was made president of the institution, an office which he held until 1868, when his health failed him owing to overwork.

In 1878, upon the death of Professor Joseph Henry, Professor Rogers was elected to the presidency of the National Academy of Sciences, the duties of which he has discharged with eminent ability. He presided at the stated session of the Academy, in April, of this year, at Washington, with his accustomed urbanity and tact, sustaining the work, which is not small, with cheerfulness, but not without some signs of exhaustion. On this last occasion he occupied the entire morning of one of the public sessions in pronouncing eulogies upon several of the deceased members of the Academy whose deaths had not been previously memorialized.

In November of last year at the meeting of the Academy at Philadelphia, President Rogers delivered a discourse in which he

reviewed with critical care some of the more important contributions to Physics which had appeared in the previous year. It was in work of this description and in his extemporaneous discourses upon scientific topics that the breadth of his views, the accuracy of his knowledge, the charm of his diction, were most conspicuous.

His public lectures before the large audiences gathered at the Lowell Institute in Boston, on various departments of physics, are remembered with pleasure by all who heard them in 1862, and subsequently. No one excelled him in the neatness and originality of his experimental demonstrations on these occasions. A writer for a Boston paper said well, on the day of his funeral: "The hundreds of men, young and old, on whom his influence bore, think of him gratefully and affectionately. All testimony is alike as to the power of his personality. He was the creator of the Institute of Technology, the inspirer of its teachers and pupils. His direct influence through contact has been very great. But fortunately the value of men to their fellows is not limited by personal acquaintance. This limitation, however, is the fate of almost every instructor. The work of teaching swallows up energy so completely that most who follow it are limited to personal influence. As one of these hard-working men, President Rogers had no time to become the public apostle of his immortal idea. But whenever he did appear as the representative of his beloved school, his voice used to ring with the utterance of it like the voice of a prophet, and his face to glow with a light which no one who saw it could ever forget. He stood for loyalty to absolute truth. He gave himself to this thought with an intensity and consecration which made it like a religion. To hear him speak of his great idea was to realize something of the divine right of science."

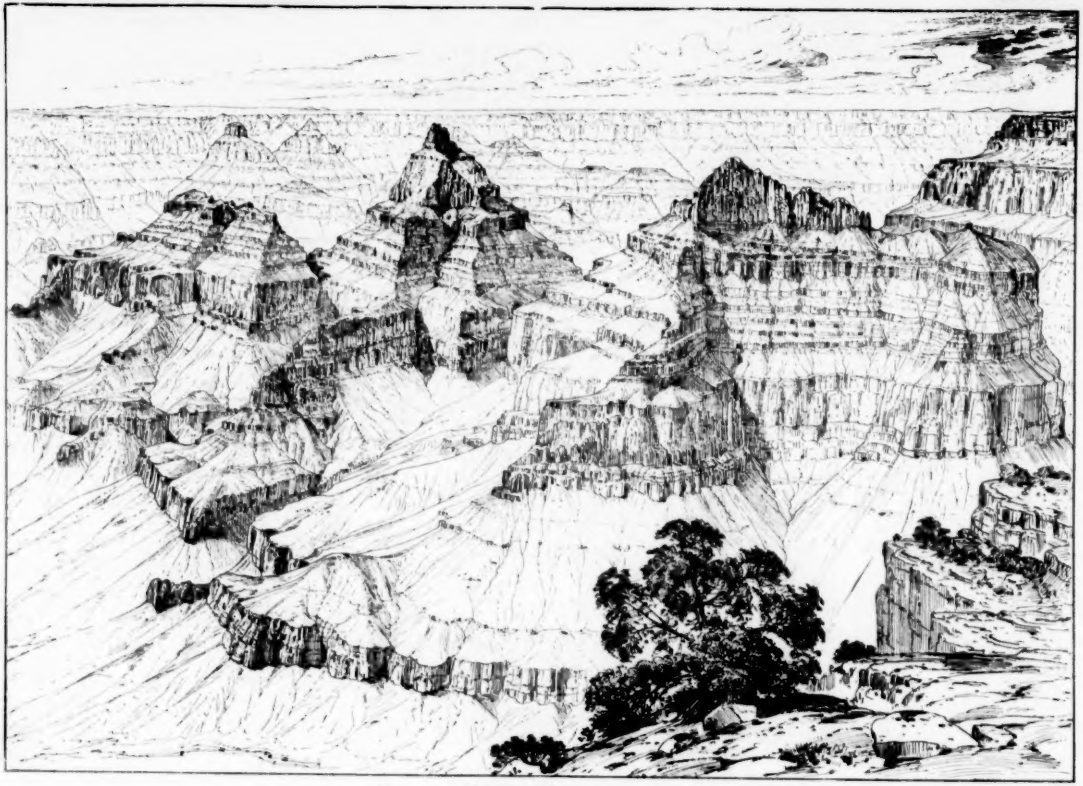
Professor Rogers published many original papers in various lines of research, in physics, in analytical chemistry, and in geology. A list of his chemical papers, both alone and in company with his brother, Robert E. Rogers, will be found in the writer's address at Northumberland, in 1874.* A full list of his contributions to the various departments of science remains to be compiled.

President Rogers was married, after his removal to Boston, to the only daughter of the late Judge James Savage, of that city, who survives him. B. S.

Dr. Augustus A. Hayes, for many years State Assayer of Massachusetts, the author of papers in Chemistry and Mineralogy, has died at the age of 76 years.

Dr. George W. Hawes, Curator of the Mineralogical Department of the National Museum at Washington, died on June 22 at Manitou Springs, Colorado. A notice of Dr. Hawes and his work in Science will be given in another number of this Journal.

* American Contributions to Chemistry, pp. 83–84.



VISHNU'S TEMPLE. COLORADO CAÑON.